A Method for Automatic Estimation of Noise Variance and SNR

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A straightforward method is proposed for estimating the noise variance and signal-to-noise ratio (SNR) of receive channels based solely on the calibration data normally acquired in a parallel imaging acquisition. This work describes the proposed method and demonstrates its feasibility. Since the proposed method uses only data acquired during image acquisition, it eliminates the need for a separate scan to determine noise variance and eliminates the possibility of incorrect registration between the noise variance acquisition and the image acquisition. In clinical practice, there are many situations in which data is collected from low SNR receive channels. This can be due to the distance from the excited region to the coil or possibly a damaged coil. Removing data from low SNR channels before parallel imaging reconstruction can improve reconstruction efficiency and in some cases improve reconstruction quality. While research has been done on coil removal [1], it was assumed that the noise variance matrix and coil sensitivities were known *a priori*. This work is motivated by a desire to have a robust method for detecting low SNR receive channels when the noise variance and coil sensitivities are not known. This study shows that low SNR channels can be correctly detected from the noise variance and SNR values estimated using the proposed method.

Theory The challenge to estimating the noise variance from a single calibration data acquisition is separating noise from signal. Image-based approaches [2] are problematic for the situation of interest, where the noise variance is desired before an image is reconstructed. Instead, the proposed method takes advantage of the conjugate symmetry of k-space to separate noise from signal. Partial k-space methods such as conjugate synthesis and homodyne phase correct the acquired data to force conjugate symmetry in k-space and then fill in data by conjugate symmetry. In the proposed method, symmetric low-resolution acquired data is used to phase correct two symmetric parts of k-space, as shown in Fig. 1. The conjugate symmetry of these two symmetric parts allows the signal to be removed from both the real and imaginary channels. The noise variance can then be computed according to Fig. 1d.

Methods A fat/water phantom was scanned without acceleration on a 1.5T scanner (Signa® HDx, GE Healthcare, Waukesha, WI) using an 8-channel body array. After acquisition, the data was modified in the following ways: 1) the data from channel three was replaced with noise to simulate a damaged coil; 2) the data values from channels 4, 5 and 6 were multiplied by ten to simulate a poorly set gain; 3) the data was artificially accelerated by a factor of two, with 20 contiguous phase encodes left in the center of k-space for calibration. The proposed method was used on the modified data to estimate the noise variance and SNR for each channel. The data set was reconstructed three different ways: 1) Using the SNR estimates to eliminate low SNR channels before passing the data to the ARC parallel imaging reconstruction [3]; 2) reconstructing all channels and using the SNR and noise variance estimates for coil weighting during combination; and 3) reconstructing all channels and using an equally weighted sum-of-squares combination.

Results Figure 2a displays the reconstructed images for each channel before acceleration; the window/level values are identical for all channels. The displayed SNR values were computed from the 20 calibration phase encodes using the proposed method. Channel 3 is correctly identified as a noisy channel with an SNR less than one. Channels 4-6 are also identified as having low SNR; the best SNR of these is 5.8, which can be unambiguously separated from channels 1,2,7,8—the lowest SNR of which is 30.0. Eliminating coils 3-6 before passing the data to the parallel imaging reconstruction results in a high SNR image (Fig. 2b). Although at a larger computational cost, reconstructing all channels and using the SNR and noise variance estimates for coil weighting during combination results in similar image quality (Fig. 2c). However, if the coils are weighted equally during combination the resulting image has considerably lower SNR (Fig 2d).

Discussion While a separate scan has the potential to determine noise variance values very accurately, the accuracy of the proposed method is sufficient for detecting and removing low SNR coils and eliminates the need for a separate scan to determine noise variance values. Because the noise variance and SNR estimates are made using data from the image acquisition, there is no possibility of incorrect registration across scans.

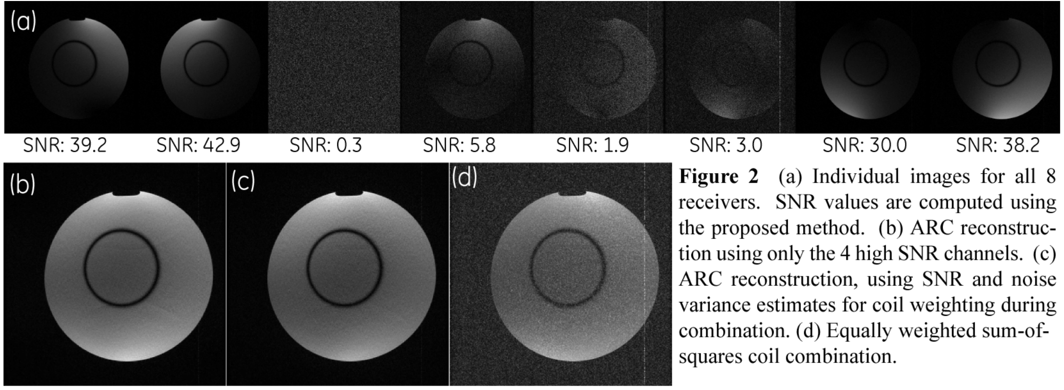
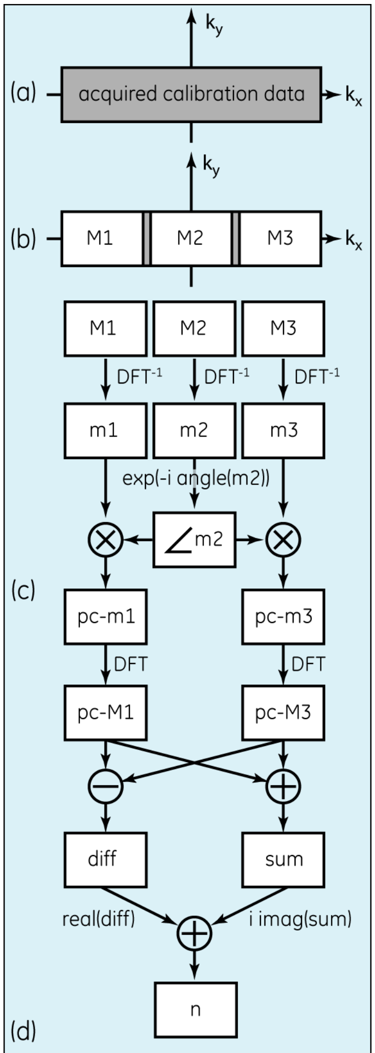


Figure 2 (a) Individual images for all 8 receivers. SNR values are computed using the proposed method. (b) ARC reconstruction using only the 4 high SNR channels. (c) ARC reconstruction, using SNR and noise variance estimates for coil weighting during combination. (d) Equally weighted sum-of-squares coil combination.



$$\sigma^2 = \frac{0.5}{N_x N_y}\sum_{k_x=1}^{N_x}\sum_{k_y=1}^{N_y}\left|n\left(k_x,k_y\right)\right|^2$$

Figure 1: Method for estimating noise variance from (a) acquired calibration data. (b) The acquired data is partitioned into 3 parts. (c) The central section (M2) is used to form a phase map; this phase map is used to phase correct the outer sections (pc-M1, pc-M3). After phase correction, the signal in pc-M1 should be the complex conjugate of the signal in pc-M3. As shown, the signal can be removed, leaving a noise image. (d) The noise variance of the acquired data can then be computed.

References

[1] Marinelli and Hardy ISMRM 2006, p3659. [2] Henkelman 1985, Med. Phys. 12 232-3. [3] Beatty et al. ISMRM 2007, p1749.