Accurate Noise Level and Noise Covariance Matrix Assessment in Phased Array Coil Without a Noise Scan

Y. Ding[1], Y-C. Chung[2], and O. P. Simonetti[1]
[1]The Ohio State University, Columbus, OH, United States, [2]Siemens Medical Solutions, Columbus, OH, United States

Introduction: Accurate noise level assessment is important to evaluate the performance of MRI hardware e.g. receiver coil, as well as the quality of an MR image. Additionally, noise measurement is needed to estimate the noise covariance matrix which is crucial in many image reconstruction algorithms [1,2]. Various methods have been proposed to measure noise retrospectively [3, 4]. However, no reliable method exists to assess noise level and noise covariance matrix in the k-space data when both signal and noise are present. In this abstract, we extend the application of a newly proposed image-based noise measurement method [5,6] to noise measurement in k-space. We will show that the noise level as well as the noise covariance matrix, usually acquired before or after image acquisition, can be accurately derived from multi-frame k-space data without deploying a separate noise scan.

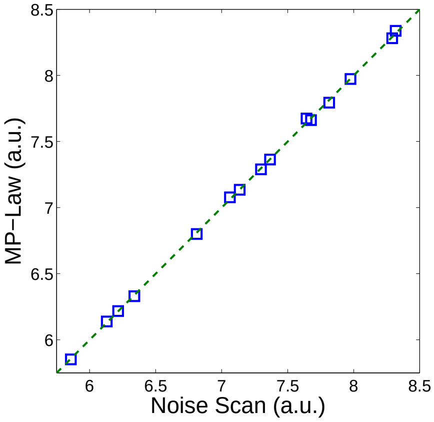

Fig. 1. Noise standard deviation measured in the noise scan k-space raw data plotted against that measured in the real-time cine raw data using the MP-law method. The dashed line indicates the identity relation.

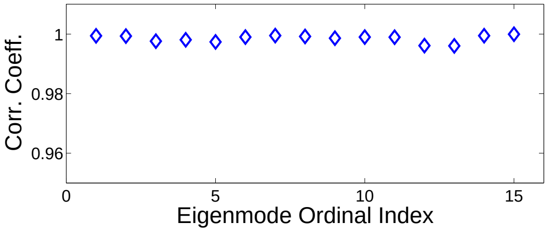

Fig. 2. The correlation coefficient between the noise covariance matrix eigenvectors evaluated by the noise scan and the MP-law method for 15 coil elements.

Theory:

Let M = frames of full k-space raw-data collected, P = coil elements used in acquisition, N = pixels in each frame. The new algorithm has four steps:

1. Combine data from P coils using sum-of-squares. The raw-data becomes a M by N matrix.
2. Apply the Karhunen-Loeve Transform (a.k.a. Principal Component Analysis) along the temporal direction (i.e., the column direction of the raw-data matrix) and find its eigenvalues and eigenvectors.
3. Use the Marcenko-Pastur (MP) law to identify the noise-only eigenmodes. (The MP-law states that the eigenvalues of the noise-only eigenmodes follow a specific probability distribution function [7]: $p(\lambda)=\frac{1}{2\pi\sigma^2\lambda\alpha}\sqrt{\max(0,(\lambda_{\max}-\lambda)(\lambda-\lambda_{\min}))}$, $\lambda_{\max,\min}=\sigma^2(1\pm\sqrt{\alpha})^2$ where σ^2 is noise variance, and α is a fitting parameter.)
4. Use the eigenvectors corresponding to noise-only eigenmodes as linear combination coefficients to reconstruct noise-only raw-data for each coil.
5. Measure noise level and calculate noise covariance matrix from these noise-only raw-data.

Methods:

Experimental data were acquired on a 1.5-T MRI system (MAGNETOM Avanto; Siemens Healthcare, Erlangen, Germany) using a water phantom. 15 coils were used (12 channels of a body matrix array coil and 3 channels from the spine coil). One 64-frame, 96 by 96 matrix real-time cine series was acquired using a spoiled gradient echo (GRE) sequence: flip angle = 15°, TR/TE=4.93ms/2.0ms, bandwidth = 500 Hz/pixel. A noise scan with no RF excitation was performed using the same parameters. The noise level calculated from the MP-law method using the real-time cine k-space data were compared to those calculated directly from the noise scan.

Results and Discussion: Fig.1 compares the noise standard deviation in each of the 15 receiver channels estimated using the proposed MP-law method with that obtained using a separate noise scan. The largest discrepancy was less than 0.5%. Fig.2 demonstrates the magnitude of the correlation coefficient between noise covariance matrix eigenvectors evaluated by these two methods was near one in all channels. In addition, the noise covariance matrix eigenvalue difference was below 1% (practically insignificant). These data show that the MP-law method can be applied to multi-frame k-space data to accurately estimate the noise level and noise covariance matrix of a phased array coil.

Conclusion: We have successfully extended the MP-law method to assess noise in each coil in k-space data without a separate noise scan in a phantom. The new approach may be used to investigate how receiver coil noise varies with physiological motion, such as the respiratory motion.

References: [1] Roemer, PB et al. Magn Reson Med 16 (1990) 192–225. [2] Pruessmann, KP et al, Magn Reson Med 42 (1999) 952-962. [3] National Manufacturers Electrical Association Standards (MS 1-2008). [4] Reeder SB, et al. Magn Reson Med 54 (2005) 748-754. [5] Ding, Y. et al. Proc. ISMRM p3810 (2009). [6] Ding, Y. et al Magn Reson Med (2009) in press. [7] Sengupta AM and Mitra PP, Phys. Rev. E 60 (1999), 3389- 3392.