Improved Coil Combination for Homodyne-Corrected Phased Array Images

R. Fobel[1], and G. J. Stanisz[1]
[1]Sunnybrook Research Institute, Toronto, ON, Canada

INTRODUCTION: Homodyne detection is a partial Fourier reconstruction method that is implemented on many commercial scanners [1]. It is commonly used to reduce the number of high-frequency phase encodes or to correct for off-centered, partial echoes to achieve shorter effective TEs. It uses low frequency k-space data to estimate the phase modulation of each image. Missing k-space lines are filled-in using Hermitian symmetry properties, after which the resulting image is demodulated [1].

Homodyne detection has many other interesting applications such as preserving negative polarity in Inversion Recovery sequences, and it has been used to separate water and fat into quadrature through specialized pulse sequences. It is also particularly useful for low-SNR images because it can be used to avoid magnitude bias [1].

Phased array coils are often used in combination with Homodyne detection for partial Fourier applications. Commercial scanners typically combine these images using the Root-Sum-of-Squares (RSS) method [2], though this practice negates many benefits of homodyne detection by throwing away the phase information. If the underlying image is real-valued (which is true for many applications) the relevant signal in each coil is aligned to the real channel after homodyne processing. It should be possible to combine the real and imaginary channels independently with appropriate weighting factors. This would preserve the complex nature of homodyne images enabling many of the above-mentioned techniques to be carried out in a multichannel experiment.

THEORY: Each phased array coil has a unique complex-valued sensitivity profile that modulates the images that it detects. The Root-Sum-of-Squares (RSS) method is often used to ensure that these images can be combined coherently in spite of their differing phase:

(1) $$S_{RSS} = \frac{\mathbf{p}^{\mathbf{T}}\mathbf{p}^*}{(\mathbf{p}^{\mathbf{T}}\mathbf{p}^*)^2} = \sqrt{\mathbf{p}^{\mathbf{T}}\mathbf{p}^*}$$

where $\mathbf{p}$ is a column vector of complex signal values from each coil, $\mathbf{T}$ is the transpose, and * is the complex conjugate. Since the phase in each image has already been demodulated, coils can be combined in such a way as to preserve their phase, but scaled by their magnitude so that they have the same contrast properties as RSS:

(2) $$S_{hom} = \frac{\mathbf{p}^{\mathbf{T}}|\mathbf{p}|}{(\mathbf{p}^{\mathbf{T}}\mathbf{p}^*)^2}$$

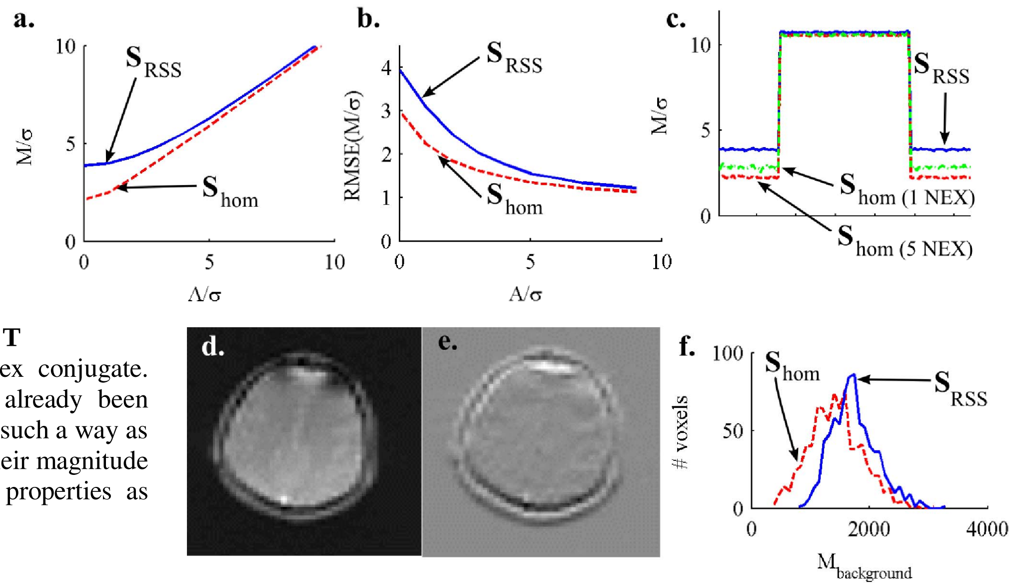

Figure 1. Simulation results comparing (a) the mean magnitude, (b) root-mean-squared error, and (c) SNR profile for the two coil combination techniques. (d) Real and (e) imaginary components of a 2D, 8-channel SPGR image of a human brain. (f) Noise histograms taken from the background of magnitude images combined using the two techniques.

METHODS: Numerical simulations were performed for an image of a uniform box function with a range of SNR values using MATLAB (Mathworks, Natick, MA). Coil sensitivities were measured from a spherical QA phantom using a GE 3T Signa scanner and an 8-channel head coil. 81 phase encodes were simulated in the vertical (phase encode) direction, and coil images were reconstructed using homodyne detection to 128x128. Coils were combined using both the standard RSS and the new technique described by Eq. 2. SPGR images of a human brain were also acquired using the same 3T system and head coil, and were reconstructed with both techniques.

RESULTS&DISCUSSION: Figures 1a and b demonstrate a significant reduction in magnitude bias with the new combination method. This is important for quantitative imaging techniques (e.g. Diffusion, Relaxometry and Magnetization Transfer) that rely on low-SNR data points. Figure c shows that complex averaging of images after they have been combined by Eq.2 allows further suppression of the noise floor (averaging of RSS magnitude images has no effect). Figures d and e show the real and imaginary channels from a human brain reconstructed with Eq. 2 (this phase information is lost with RSS). Figure f provides another demonstration of the reduced noise floor with a 20x20 voxel histogram from a background region of the SPGR images.

CONCLUSION: We have demonstrated a simple way to combine multichannel homodyne images that preserves their phase information. This extends the many useful applications of homodyne-detection to phased array imaging. For many users already using homodyne detection as a partial Fourier technique, this combination method can efficiently reduce low-SNR magnitude bias.

REFERENCES: [1] Noll (1991) *IEEE Trans Med Imag* **10**(2), 154-163. [2] Roemer (1990) *MRM* **16**(2), 192-225.