Sensitivity Enhanced Single Point Imaging

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Introduction

Single Point Imaging [1, 2, 3, 4] is well-known to suffer from a low SNR due to inefficient spin signal utilization. A flexible sensitivity enhancement procedure is proposed.

Methods

In Single Point Imaging (SPI) with rf pulse-sampling time intervals $T_E$, the maximum feasible ADC sampling time is $\tau \approx T_E / N$ independent of whether or not the phase encoding gradients are switched off during sampling. Short $T_E$ times, demanded by short $T_2$ species and large $B_0$ inhomogeneities, result in extremely high pixel bandwidths and a poor SNR.

To enhance the SNR, we propose to collect $M > 1$ data samples per excitation. Primarily, the $M$ data sets are reconstructed independently. As a final step, the image sets are combined into one image set with enhanced SNR. It may be noted that even a few additional samples lead to dramatic improvements: At a 128 matrix size, the SNR of SPI is $\sqrt{1/128} \approx 8.8\%$ compared to FLASH. Optimum combination of only e.g. $M = 16$ samples during 12.5% of the $T_E$ time rises the SNR by a factor of four or 35% of the total enhancement possible.

The crucial step is the combination of the $M$ data sets with different $T_E$. First, if the phase encoding gradients are active during sampling, the raw data sets reveal different k-space encodings. An image set rezoom procedure has to be applied prior to combination, e.g. by interpolation of the reconstructed images or within the Fourier transform. A second phenomenon to be dealt with is the phase difference between the $M$ pixels of each spatial position due to local offresonance. Straightforward complex summation is thus infeasible. One remedy is to combine the image sets phase-insensitive, e.g. by taking the square root of the sum of the squared magnitude image sets. Alternatively, one may fit and remove any phase linearly varying with the encoding time $T_{E_k}$, and then perform a complex summation, or take the Fourier transform along the $T_E$ dimension and e.g. choose the pixel intensity according to the highest peak in the spectrum. Implicitly, the latter approaches additionally yield $\Delta B_0$ field maps.

Implementation and Results

The proposed sensitivity enhancement method was incorporated in a RApid Single Point (RASP) imaging sequence [4] with $T_E = 280 \mu s$, $T_R = 500 \mu s$, 2 $\mu s$ ADC dwell time, 128$^3$ matrix and $430^3\text{mm}^3$ FoV on a clinical 1.5$T$ Siemens Vision scanner. The total measurement time was 17 : 29 min. $M = 16$ samples with $T_E = 248 \ldots 280 \mu s$ were collected after each excitation. The necessary FoV rezooming by 1.13 $\ldots 1.00$ was performed by the chirp $z$-transform. Both squareroot-sum-squared and Fourier transform-peak extraction image combinations were implemented and tested on an iron-loaded water phantom inside a CP head coil.

Both combination schemes resulted in the anticipated SNR improvement from 15.2 with the original RASP to 56.4 and 58.2 with 16 samples, representing a gain of 3.71 and 3.56. Both combination methods performed approximately equal. The resolution loss due to the addition of zoomed-up images was unrecognizable. The $B_0$ inhomogeneity tolerance of the original RASP sequence remained undegraded.

Discussion and Conclusion

In Single Point Imaging, additional ADC samples per excitation are able to yield considerable SNR enhancements. A major portion of the total improvement is already gained with only a few samples, where the whole data set is still ‘compact’ and image blurring and $T_2$ decay are small.

References