Fast Shimming strategy using intermediate space conversion

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Introduction Because of external magnetic field inhomogeneity, MRI has signal loss, poor fat suppression, image blurring, and image. In case of brain, different magnetic susceptibility at tissue/air interface causes significant field distortion. To remove this inhomogeneity, it is vital to shim. Since shimming is needed per subject, it is considered a time-consuming process and even more so for 3D shimming. Several methods for fast shimming (such as FASTMAP[1], FLATNESS[2]) exist. In this abstract, we introduce an in vivo volumetric shim strategy which can be performed in a very short time using an intermediate space conversion idea. Linear shimming and high-order shimming approaches are presented.

Theory The proposed method relies on determining the basis and finding the shim coefficients from an intermediate space conversion of the k-space data rather than fulling converting it into the image space like conventional shimming methods (Fig. 1). The k-space data are sparsely acquired in a radial fashion (Fig. 2). For the case of linear shimming, only three lines of k-space are acquired (k_x,k_y,k_z axis). For the case of high-order shimming, more than three lines are acquired. These projection data are then processed for determining the required shim coefficients. For linear shimming, taking the phase directly from the acquisition, a 'projected' field map is determined. A least squares fit is used to determine the required shim coefficients. The least squares fit can be used since correlation of the 'projected' field maps are guaranteed and as long as wrapping of the phase values in the ROI do not exist during the acquisition. For high-order shimming, the phase of the projections cannot be directly used due to the correlation of the 'projected' field map. Hence, a simple back-projection of the highly under-sampled data is performed, followed by a masking procedure to eliminate regions with poor signal magnitude contribution. Now, a least squares fit can be used. In both cases, the number of required k-space line acquisitions is significantly reduced compared to full 3D acquisitions.

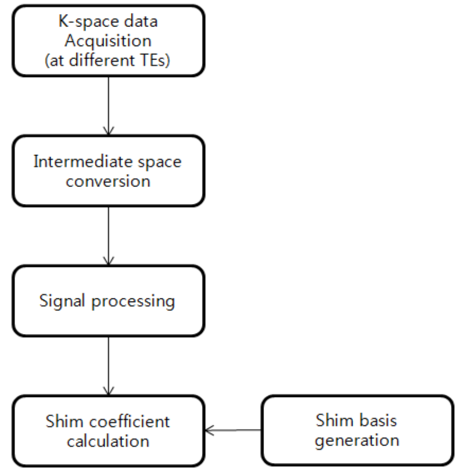

Figure 1. The proposed algorithm using intermediate space conversion for obtaining shim coefficient in very short time.

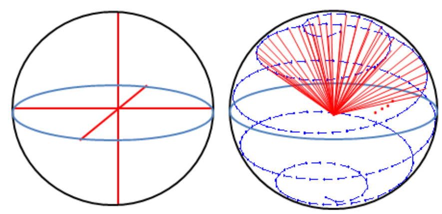

Figure 2. Used k-space trajectory of linear shimming(left), and high-order shimming(right)

Materials and Method The proposed method was implemented on a 3 Tesla scanner. Phantom and in vivo data were obtained with TE=4, 6[ms] and TR=10[ms]. For the shim basis generation, direct measurement from the scanner was employed for linear shimming, whereas a spherical harmonic basis was used for high order shimming. In all, the linear shimming required 11 TRs(including 5 dummy pulses) for data set acquisition. For high order shimming, the performance was evaluated by varying the number of radial lines acquired. The overall performance was compared with a full 3D gradient-echo acquisition (field of view 256x256x256 mm^3, matrix 64x64x64, echo time delay 2ms).

Result and discussion Fig 3 and Fig 4 show the result of linear and high order shimming of the in vivo brain, respectively. In both cases, removal of macroscopic B0 inhomogeneity is similar using our proposed case vs conventional method. For the high order shimming acquisition, 160 radial lines were collected initially. Table 1 provides quantitative values of the performance and the overall procedure time of the methods. Fig 5 demonstrates the standard deviation of the resultant field map as a function of radial lines used for high order shimming. The performance is similar for radial lines to as few as 80 arms. Theoretically, high order shimming can be performed with six line acquisition[1]. However, in this case, a 1D line selective RF pulse is used to collect radial lines in image spaces. This involved changing the RF pulses for each measurement and less SNR. Our approach uses a simple slab selective RF pulse with high SNR. While linear shimming was performed using only 3 acquisitions, high order shimming required more radial lines than theoretically needed. The linear shimming required that no phase wraps were inside the ROI. This requirement seemed to be easily met with modern day clinical scanners (4 ppm over 25.6cm FOV). High order shimming required a simple back-projection scheme since directly using phase of the radial k-space data did not guarantee the orthogonality of shims. This lengthened the overall procedure, however dedicated processing algorithms can be used which can significantly reduce the time.

		Linear		High-order	
		phantom	In vivo	phantom	In vivo
Before shimming [Hz]		36.48	43.45	37.80	46.17
After shimming [Hz]	Conventional method (using 3D full data)	6.06	15.16	7.31	14.97
	Proposed method	6.49	15.92	6.30	11.34
Total time [sec]	Conventional method	40			
	Proposed method	0.4		8 (3 sec scan time and 5 sec recon time)	

Table 1. standard deviation of field map.

Conclusion We proposed a fast 3D shimming strategy using an intermediate space conversion scheme. The results demonstrate our scheme is robust and shimming performance is decidedly useful to reduce the shim time(linear shim(~0.4s) and in high-order shim(~8s)).

Acknowledgements Samsung Electronics

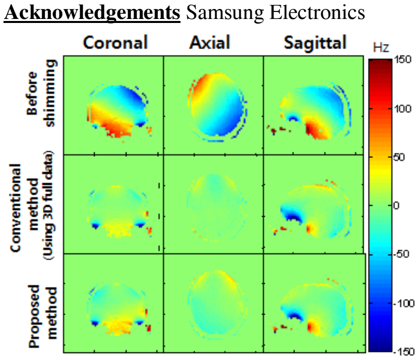

Figure 3. Result field map of linear shimming (in vivo brain).

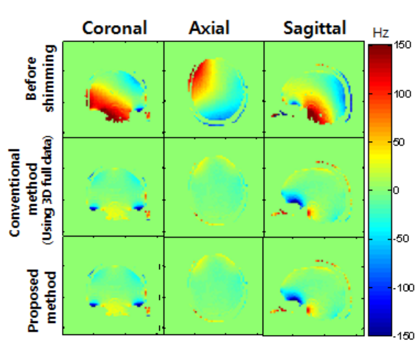

Figure 4. Result field map of high-order shimming (in vivo brain).

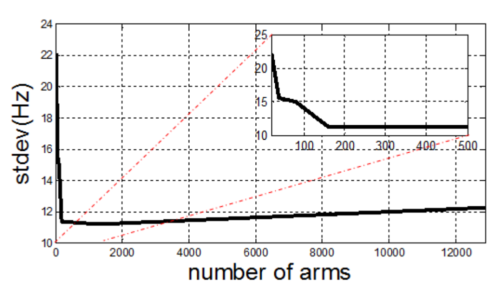

Figure 5. used arm vs. Standard deviation of the result field map. In this case, stdev of result of conventional method is 14.97 Hz. (full nyquist arm number 12868).

References 1.Gruetter R, et al, JMR 1992;96:323-334. 2. Jun shen, et al, MRM, 1990;42:1082-1088.