Multiple Reconstruction for Producing High-Resolution Images

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INTRODUCTION This paper presents a new MR imaging technique in which reconstructed images have higher resolution than that of Fourier transform-based (FT) imaging on condition that the same size of data is used. The signal obtained in the Phase-Scrambling Fourier Transform imaging technique (PSFT) can be transformed to the description of Fresnel transform equation. Therefore, image reconstruction can be performed by not only inverse FT, but also by inverse Fresnel transform. In general, the field-of-view (FOV) of reconstructed images and spatial resolution are different in each reconstruction method. By combining these two images, we can obtain an image that has a higher resolution than standard imaging technique.

SIGNAL DESCRIPTION AND IMAGE RECONSTRUCTION In the proposed image reconstruction method, PSFT, in which a quadratic field gradient is added to the pulse sequence of conventional FT imaging in synchronization with the field gradient for phase encoding, is used. The signal obtained in PSFT is given by the following equation[1];

$$v(k_x,k_y)=\int\int_{-\infty}^{\infty}\rho(x,y)\exp\{-j\gamma b\tau(x^2+y^2)\}\exp\{-j(k_x x+k_y y)\}dxdy, \quad (1)$$

where $\rho(x,y)$ represents the spin density distribution in the subject, γ is the magnetogyric ratio, b and τ are the coefficient and impressing time, respectively, of the quadratic field gradient.

Equation (1) can be rewritten as Fresnel transform equation by using the variable substitutions $x'=-k_x/2\gamma b\tau$ and $y'=-k_y/2\gamma b\tau$ [2],

$$v(x',y')\exp\{-j\gamma b\tau(x'^2+y'^2)\}=\int\int_{-\infty}^{\infty}\rho(x,y)\exp\{-j\gamma b\tau[(x'-x)^2+(y'-y)^2]\}dxdy. \quad (2)$$

Subject images can be obtained by two kind of reconstruction method. One is a standard FT method using the signal of Eq.(1). In this case, spatial resolution and FOV become $\Delta x(=2\pi/N\Delta k_x)$ and $N\Delta x(=2\pi/\Delta k_x)$, respectively. The other method is the inverse filtering(IF) method using the Fresnel transformed signal, since the right-hand of Eq.(2) is written as a convolution integral equation. In this method, the pixel width of reconstructed image is the same as $\Delta x'(=-\Delta k_x/2\gamma b\tau)$ and FOV becomes $N\,\Delta x'$. So, we can set the FOV of image independently to each other reconstruction method.

Let note the subject width be W and consider the case when $N\Delta x'>W>N\Delta x$ is satisfied. FT based reconstruction provides images having higher resolution compared to standard imaging, however, aliasing will appear in the image domain. Whereas IF reconstruction provides almost alias-free image having standard spatial resolution, since aliasing appears in the Fourier transformed domain of Fresnel transformed signal, which is not an image space. By replacing aliasing area in the high-resolution image with the corresponding part in the standard resolution one, we can obtain an image, in which central part has an improved resolution.

EXPERIMENTS Experiments were performed using a hand-made ultra-low-field MRI scanner (0.0187T). Figure 1 shows the results of reconstructed images using yuzu orange. Imaging parameters are $\Delta x'$=0.12cm, Δx=0.075cm, $\gamma b\tau$=7.8 rad/cm^2, size of reconstructed image are enlarged from 64x64 to 128x128 to secure the high-resolution. It was shown that center of image have higher resolution compared to standard FT-based reconstructed image.

CONCLUSION A new MR high-resolution imaging technique is presented and demonstrated. It was shown that proposed reconstruction technique had the capability to produce images having higher resolution compared to standard Fourier transform imaging technique on condition that the same size of data is used.

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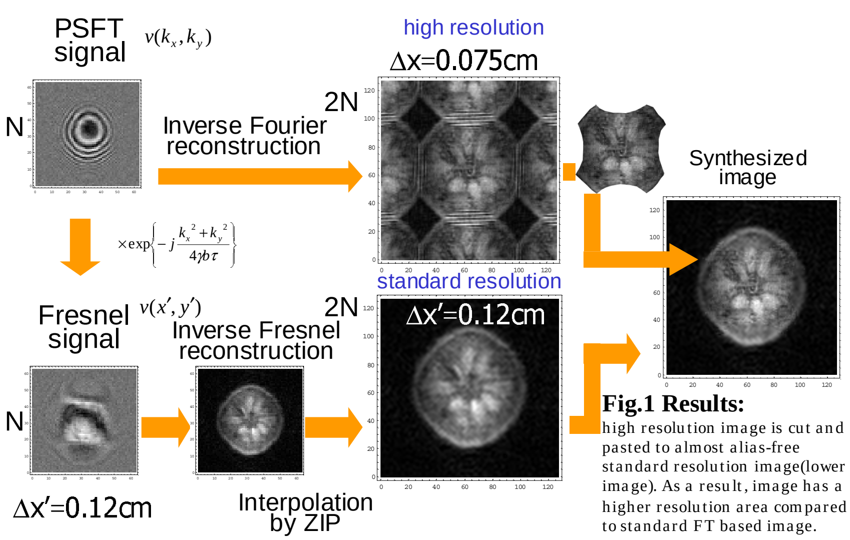

Fig.1 Results: high resolution image is cut and pasted to almost alias-free standard resolution image(lower image). As a result, image has a higher resolution area compared to standard FT based image.