A Partial Fourier Reconstruction Method for Radially Acquired Data with Variable TE

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Introduction: Lately, there has been an increasing interest in radial MRI due to its robustness to motion and the possibility of using partial k-space data to manipulate contrast[1-3]. Recently it was demonstrated that a radial fast spin-echo (RAD-FSE)[1,2] or a radial gradient and spin-echo (RAD-GRASE)[3] method can be used to obtain high-resolution images at various effective TEs from a single k-space data set. These images are then used to calculate T2 (or T2*) maps for tissue characterization. So far, these radial acquisition strategies are based on the collection of full radial lines (views). Higher time efficiency can be achieved, however, if half radial views are collected and the missing data points are estimated using partial Fourier reconstruction methods[4].

Partial Fourier reconstruction algorithms have been developed for radial data[5-7]. One detailed description is given by Noll et al[5]. In their method, only half of each radial view is collected and the collected half views are ordered such that each uncollected segment is between collected segments, as illustrated in Fig. 1. The uncollected k-space points that are within the Nyquist radius are calculated using interpolation. The uncollected k-space points that are outside the Nyquist radius are calculated using homodyne detection[4]. The homodyne detection is performed in the projection domain with the assumption that each projection has a slowly varying phase. With this assumption, the phase of each projection is estimated from the phase of a low resolution projection computed using only the k-space points within the Nyquist radius. Once all the projections have been calculated, the image is reconstructed using either filtered backprojection or regridding.

Although this method works well in general, problems arise when neighboring views are collected with different signal weighting. For example, if data are collected with a RAD-FSE pulse sequence, the optimal angular ordering of views requires that neighboring views are collected at different TEs[8]. In this case, the estimation of the uncollected points based on neighboring views yields artifacts in the images. To circumvent these problems, we propose a modified partial Fourier reconstruction method. This method is based on a single-TE interpolation scheme.

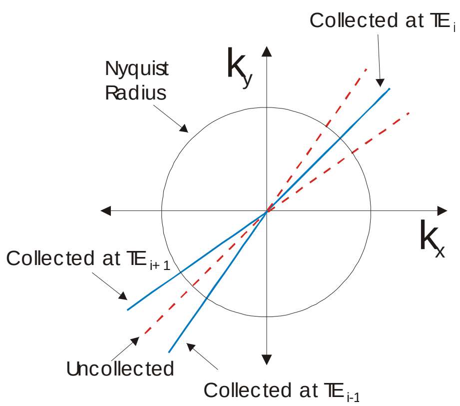

Fig. 1.

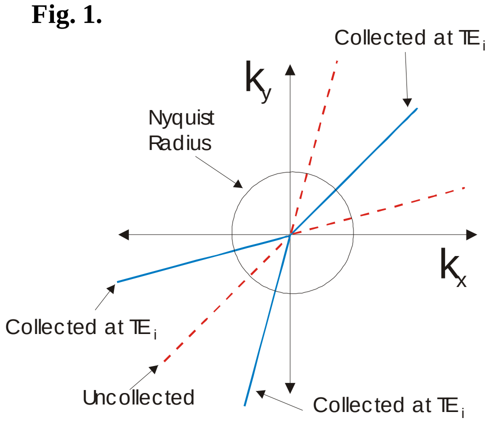

Fig. 2.

Methods: The single-TE interpolation method consists of using only the views collected at a specific TE to calculate the uncollected k-space points of a radial view. This is illustrated in Fig. 2, where the uncollected points are interpolated using only data acquired at TE_i. It should be noted that the Nyquist radius in Fig. 2 is smaller than the Nyquist radius in Fig. 1.

For evaluating the proposed method we acquired data using a RAD-FSE sequence. The parameters used in the acquisition were ETL=32, receiver bandwidth=±32 kHz, number of sampled points along a view=256, number of views=256. With these parameters, the echo spacing (space between 180^o rf pulses) was equal to 9 ms. Thus, radial views were collected with TEs ranging from 9 to 288 ms. To simulate partial acquisition, half of the points for each view were deleted to produce a data set as illustrated in Fig. 1.

Results and Discussion: The method shown in Fig. 1 was first used to reconstruct an image using the partial data set. The single-TE interpolation method (Fig. 2) was used next to reconstruct an image using the same partial data. To evaluate these two half Fourier methods, we compare the images reconstructed with each of these methods to an image reconstructed using the full k-space data set (i.e. 256 full radial views). Figure 3a shows the image reconstructed using the full k-space data set. Figure 3b shows the image reconstructed from the 256 half views using the method depicted in Fig. 1. As noted, there is significant smearing in this image. The absolute error between the images in Figs. 3a and 3b is shown in Fig. 3c. The mean squared error (MSE) between these two images is 512.99. The image reconstructed using the single-TE interpolation method is shown in Fig. 3d. As noted, the smearing is significantly reduced in this image. This is also evidenced by the absolute error between the images in Fig. 3a and 3d (Fig. 3e) and the smaller MSE of 41.90.

Conclusion: A half Fourier radial method has been developed to reconstruct images from half radial views acquired with different T2 weighting. The method has been demonstrated for a radial fast spin-echo data set. A similar algorithm can be derived to reconstruct data with other pulse sequences such as radial gradient and spin-echo where variations due to T2 and phase occur during data acquisition.

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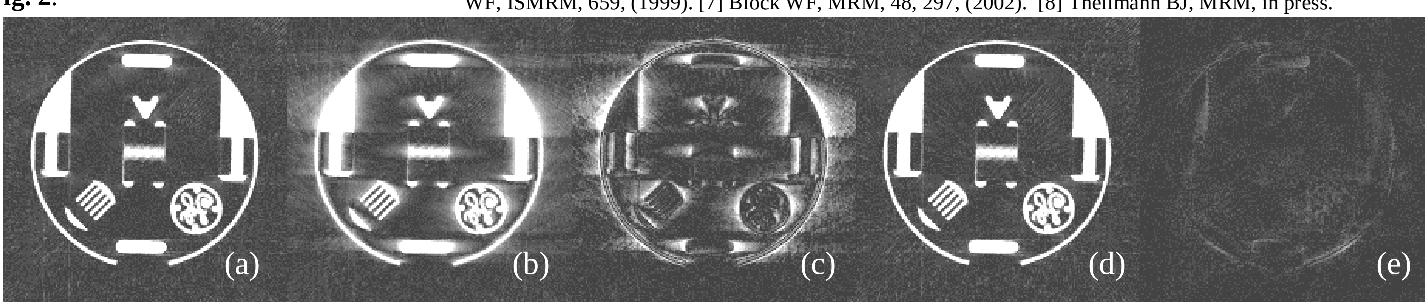

Fig. 3: (a) Image reconstructed from full radial views. (b) Image reconstructed using half radial views with the method in Fig. 1. (c) Absolute error between (a) and (b). (d) Image reconstructed using half radial views with the method in Fig. 2. (e) Absolute error between (a) and (d).