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A New Approach to Reduce Diffusion Effect in NMR Microscopy

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Several authors have pointed to NMR microscopy as a new direction to be followed by NMR imaging. The main drawbacks to microscopic imaging are the signal-to-noise ratio and the reduction of resolution imposed by the intrinsic random motion (diffusion) of the nuclei under observation in the presence of the high intensity magnetic field gradients. The diffusion effect is indeed responsible for both phenomena. The usual techniques employed (3D Projection Reconstruction, Diffusion Effect Reduced Gradient Echo, DRG)[1,2] have in common the fact that they all acquire the NMR signal, either a FID or Echo, in the presence of a strong magnetic field "readout gradient". The effect on SNR of the diffusion phenomena was satisfactorily solved by the new approaches on the recalled Echo method as the DRG technique (that uses direct Fourier reconstruction algorithms).

Still remaining however is the effect on resolution. The purpose of this work is to introduce a new approach to direct Fourier reconstruction techniques that permit acquisition of images with absolutely no restriction on resolution imposed by diffusion or other T_2-like phenomena.

Method:

The general method for NMR imaging can be thought as a space transform of a function S(K) sampled in the "signal space" K. The way of sampling, defined as a trajectory on that space, defines the technique used. There are well known k-space trajectories for the different techniques proposed and that for DRG can be seen in Figure 1.

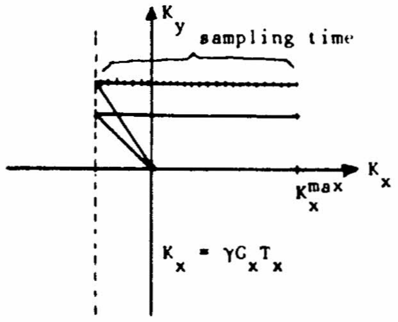

Figure 1. K-space trajectory for the Diffusion Effect Reduced Gradient Echo (DRG)[2]. The excursion of the variable $K_x = \gamma G_x T_x$ is reduced to provide less time of diffusion in the presence of G_x without affecting absolute resolution.

The purpose of our scheme is to eliminate the excursion of the signal in the presence of the read gradient, reducing the number of acquisitions to one for each induced signal. To compensate, the three gradients are applied as phase encoding gradients (in 3D imaging) as illustrated in figure 2. The diffusion limited resolution inherent to the above techniques[2],

$$(\Delta r)_D = \sqrt{\frac{2}{3} D T_{acq}},$$

does not apply to our proposition, since $T_{acq.} = 0$.

The only drawback of our technique is the increase of the total experiment time. For a 3D data set of NxNxN points, N^3 FIDs must be generated against N^2 FIDs for conventional 3D techniques. This is however compensated by the drastic reduction on the receiver bandwidth (BW) since the sampled signal has only low frequency components (FID without gradient applied). The limit value of BW is only determined by the repetition time TR in the same way as in the BOXCAR Averaging. The resultant improvement in SNR leads to less number of averages and consequent reduction in total acquisition time.

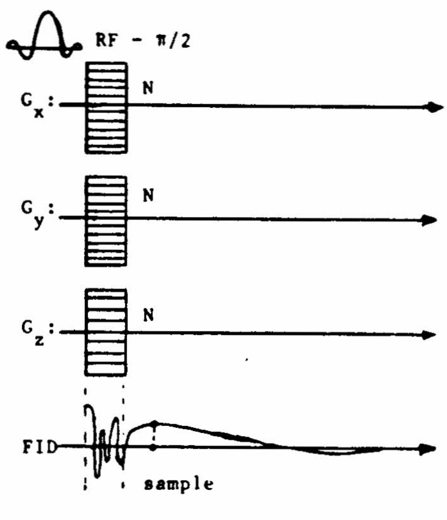

Figure 2. Scheme for the proposed technique. The signal $S(K_x, K_y, K_z)$ is acquired only once for each value of $|G_x, G_y, G_z|$.

References:

1. Lauterbur, P.C., IEEE Trans. Nucl. Sci., 31, 1010 (1984).
2. Cho, Z.H. et al, Med. Phys., 15 (6), 815 (1988).

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