Excitation k-Space and uTE MRI

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Introduction MRI consists of both the spatially selective excitation of magnetization, and the spatial encoding and localization of the signal. The reception side of MRI was developed first [1], and was described in terms of k-space. Excitation k-space came later [2], and was motivated in large part by what had already been developed on the reception side. In fact, any imaging pulse can be reversed to produce a related, and often interesting pulse sequence.

Reception k-space The data collected in MRI can be described as samples acquired along a trajectory in spatial frequency, or k-space, which is simply the integral of the gradient waveform. An example of a slice-selective pulse sequence that traces out a spiral in spatial frequency is shown in Fig. 1a. Also show is the excited slice, and the isocenter voxel.

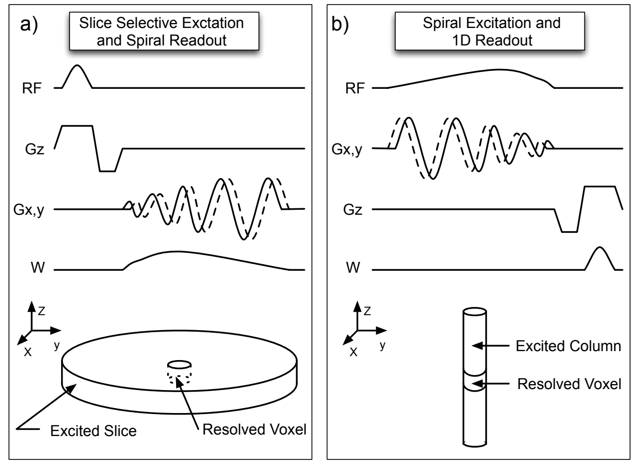

Figure 1: A slice selective spiral pulse sequence (left) can be reversed to form a column selective, 1D resolved pulse sequence. W is the reconstruction weighting, which becomes the RF pulse when reverse. One resolved voxel is exactly the same with both pulse sequences. Other voxels can be resolved in the readout dimensions.

Excitation k-space Motivated by the paper by Bottomley and Hardy [3], we realized that imaging and excitation where duals of each other, and that the same ideas that govern imaging and reconstruction apply equally to excitation. A 2D excitation pulse could be designed simply by playing a spiral imaging sequence backwards, with the reconstruction weighting used for the RF pulse, shown in Fig. 1b. The isocenter voxel is the same in as the original imaging sequence. Other voxels can be resolved in the readout dimensions, which differ between the two.

This started a search for other interesting pulses. The dual of the EPI imaging sequence is the spectral-spatial pulse [4], which can also be a 2D spatial pulse. The 2DFT pulse sequence is its own dual. Interleaving in excitation k-space has the same benefits as in reception k-space, shorter gradients and less off-resonance effects [5].

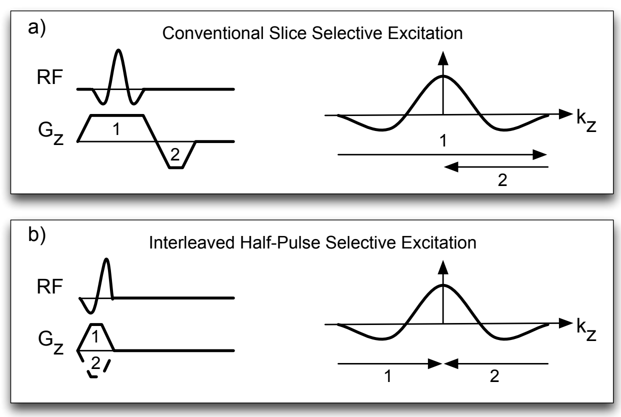

Figure 2: Conventional slice selective excitation (a), and an interleaved half pulse excitation (b).

In writing [2], we were looking for a simple example of interleaving, and came up with the 1D example of two half pulses with opposite gradient polarities [6]. Since the second half of the excitation pulse, and the refocusing gradient are eliminated, this allows a very short echo time when combined with a radial readout. Unfortunately, this produces images with very little contrast! This led to the development of long T2 suppression pulses [6]. Short T2 contrast mechanisms continue to be an active research topic.

References

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