Selective Excitation without Gradients with Accelerated TRASE

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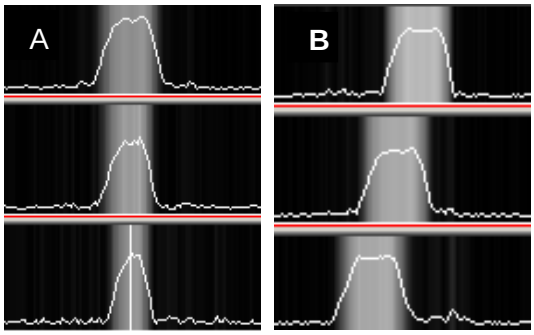
Introduction: Spatially-selective excitation is a fundamental building block of most MRI pulse sequences. Slice selection is conventionally implemented using a shaped RF pulse applied simultaneously with a gradient in magnetic gradient strength, or equivalently, a gradient in resonant frequency. We present a new method ("TRASE") that replaces the role of the frequency gradient with RF phase gradients. We have previously demonstrated one dimensional encoding using the TRASE method (1,2) and we describe elsewhere the extension of this to 2D encoding. In this abstract we show how TRASE k-space encoding can be applied to slice selection.

K-Space Traversal by TRASE: Frequency-selective excitation can be described as a process of k-space traversal, with the deposition of RF energy (causing excitation) along the trajectory (4). The TRASE method of slice selection can also be understood in exactly this way, the difference however being in the physical means by which the k-space traversal is achieved.

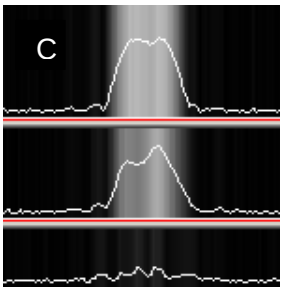
Coil: TRASE is based upon RF coils of uniform B1 magnitude, but different linear B1 phase gradients. Let us assign a k value, k_C, to each coil equal to the number of cycles/mm of the phase gradient, thus $k_C = G_C /360$, where G_C is the phase gradient in deg/mm. The effect of a refocusing pulse with such a coil is a jump about the "*coil k-space origin*", k_C. **Coil Pair:** Consequently, successive refocusing pulses applied alternately to two coils A & B move excited magnetization in k-space along an encoding access defined (in both direction and magnitude) by ($k_C^A - k_C^B$). A train of alternating refocusing pulses (i.e. ABAB etc) then serves to produce a k-space traversal, with a spatial resolution proportional to echo train length. For an AB train of N pulses using a pair of fields with k values +/- k_C, the maximum k-value is $4Nk_C$. The FOV (aliasing period) is the reciprocal of the k-space point separation, which in the simplest 1D 2-coil case is $1/4k_C$. So, using this k-space traversal method, the application of small flip-angle RF pulses between each refocusing pulse will result in selective excitation, following Pauly (4).

Experimental Results: Experimental results were obtained using a 0.2 Tesla open MRI system controlled by an NRC TMX MRI console (3). For all 1D slice profiles shown an array of two sequentially-selected spiral birdcage coils were used to produce RF phase gradient fields of +/- 1.25deg/mm. The active coil is selected and enabled under pulse sequence control by use of PIN diode networks. The TRASE technique only requires a single transmitter channel and a single receive channel.

The phantom was a 25mm diameter syringe filled with water to a length of 50mm. All experimental implementations were verified by integrated simulation utilizing the TMX console software (3). All refocusing pulses were implemented as 1.6ms 90x-180y-90x composite pulses. Slice profiles were obtained by following the TRASE slice selection process by a conventional frequency-encoded gradient echo readout. A sinc envelope function was used to set the areas of N_P 800us small flip angle hard excitation pulses (transmitted on the B coil) one between each refocusing pulse in an AB echo train. This was followed by $N_P/2$ refocusing pulses in reversed order (BA) to refocus across the slice.

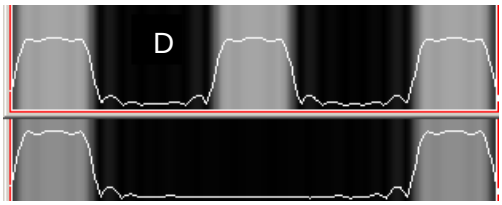


Slice Width: Slice width is controlled by the width of the sinc function in k-space, which is proportional to pulse train length. Experimental profiles from N_P=32,40,50 pulses (16mm, 12.5mm, 10mm widths) are shown (*Fig.A).* **Slice Shift:** Slice shift is achieved by modification of pulse phases. For a coil A of phase gradient Ga (deg/mm), a phase shift of (Ga .dx) applied to all RF pulses on coil A corresponds to a spatial shift of dx mm. Alternatively, for a pair of coils of gradients +G and –G, phase shifts of +G.dx/2 and –G.dx/2 respectively will also result in a spatial slice shift of dx mm (Fig. B). **Flip Angle:** The flip angle of the excited slice is adjusted by scaling the area of each of the small angle excitation pulses (Fig.C: 90deg, 45 deg, 0 deg).



k-Space Serial Transmit Acceleration: Slice selection implementation may be improved by use of a technique to accelerate k-space traversal. Firstly we note that excitation with a phase gradient coil results in magnetization entering the k-space plane at an off-center position (k_C). Secondly, since N_C coils are available, at any time in the pulse sequence we may excite to N_C distinct k-space locations by rapid sequential switching between the N_C coils. We refer to this as "serial transmit acceleration". This is of considerable practical benefit in allowing echo train lengths to be reduced and/or k-space coverage improved. A simulation of slice selection (N_P=20) using only A pulses for the small flip angles (un-accelerated, Fig.D upper), using alternate small flip excitations on A & B coils (accelerated), (Fig D. lower). The acceleration doubles the k-space density and the FOV (aliasing period) relative to excitation with A only. Addition of a third uniform coil results in a further doubling of the k-space sampling density.

Conclusions: We have introduced a new RF-only method of slice selection which requires neither a gradient in resonant frequency nor shaped RF pulses. Experimental results show that slice profile, width, position and flip angle are all fully selectable. A technique is available to accelerate k-space coverage. In addition to a switchable coil array, TRASE techniques only require a magnet, a single transmit channel and a single receive channel. Since TRASE is k-space based many existing k-space concepts and techniques, such as segmented excitation, are directly applicable. There are many potential applications, including use with TRASE 2D encoding for complete MRI without a frequency gradient sub-system.



References: 1) S.B. King, , P. Latta, V. Volotovskyy, J.C. Sharp, B. Tomanek, ISMRM p.680 May 2007; **(2)** S. B. King, D. Yin, S. Thingvold, J.C. Sharp, B. Tomanek, ISMRM, Seattle, p.2628 2006; **(3)** J. Sharp, D. Yin, R. Tyson, K. Lo, B. Tomanek, ISMRM, Seattle, p.1351 2006; **(4)** Pauly-J, Nishimura-D, Macovski-A J.M.R. 81 43-56 (1989). Acknowledgments: R. Bernhardt.