Single Point Imaging with minimized phase encoding interval

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Introduction

The Single Point Imaging (SPI) technique has already proved to be useful for studying of samples with a very short transverse relaxation time. We propose a modification of SPI, based on the minimization of the phase encoding interval for further signal to noise ratio (SNR) optimization. This method is particularly beneficial when the maximum gradient amplitude is limited and the resulting SNR suffers from the T_2-related signal attenuation.

Methods

The SPI sequence is a pure phase-encoding technique, in which a single datum point in k-space is acquired for each repetition time T_R (Fig. 1a). Sometimes SPI used to be referred to as constant time imaging (SPI/CTI) because the encoding time T_P remains constant during the whole experiment. It has been shown that the optimal SNR ratio is achieved when Tp= $T^*_2/2$ [1]. This means that for samples with short T_2, the demand for maximal gradient amplitude is increasing (Fig.2). Although, for the systems equipped with strong gradients, it is usually not a problem to achieve optimal Tp, it might be out of reach for the medical scanners and/or systems used for *in vivo* applications. Moreover, in many biological applications it is necessary to optimize sensitivity, especially when imaging nuclei with a low natural abundance [2]. In order to increase the sensitivity and avoid the problem with gradient amplitude restriction, we propose modification of the SPI sequence, based on the utilization of the variable phase encoding interval (SPI/VTI). The timing diagram of SPI/VTI is shown in Fig. 1b. In SPI/VTI the spatial encoding is performed by variation of the phase encoding interval rather than by a change of gradient amplitude. Fig.3 shows the simulated comparison of the relative SNR performance for both methods. Another aspect to be considered when non-constant phase encoding is used, is the final resolution as affected by the signal variation. The simulation of the line spread function (LSF) variation affected by T_2 relaxation is shown in Fig.4. From the diagram it can be seen that for the $T_p/T_2 > 3.5$ the effect of the LSF becomes crucial and a limiting factor of the resolution.

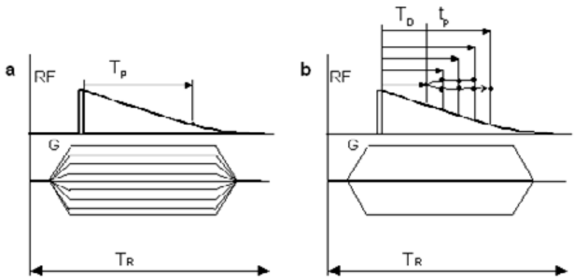

Fig.1 (a) in the original SPI/CTI sequence, a broad band α pulse is applied in the presence of the phase encoding gradient, following with the constant phase encoding period T_P and single data point acquisition; (b) proposed SPI/VTI sequence has a variable phase encoding interval t_p, which is varying in the interval t_P=<T_D, T_p>

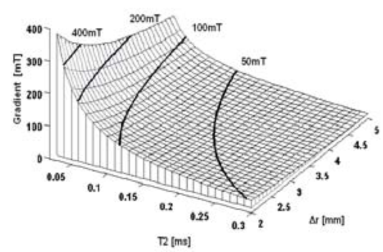

Fig.2 The demand for gradient magnitude calculated as a function of T_2 relaxation and resolution Δr. The gradient is calculated for the optimal SNR performance.

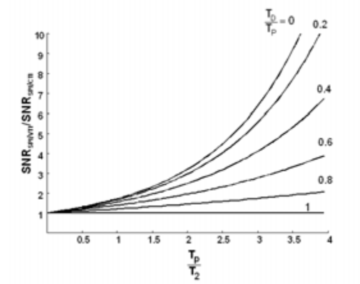

Fig.3 The SNR comparison for SPI/VTI and SPI/CTI. Calculations assume that both experiments employ identical experimental parameters, and in the case of SPI/CTI, t_p varies in the interval <T_D, T_p>.

Results and Discussion

The SPI sequence with variable phase encoding time was implemented on an 11.7 T spectrometer equipped with a 72-mm self-shielded Magnex gradient system, SGRAD 123/72/S, and connected to a Bruker Avance DRX console. In order to minimize acoustic vibration, the gradient shape adjustment technique was used [3]. To compare SPI/CTI and SPI/VTI performance, images of a rubber stopper from a test-tube (T_2=72μs) were acquired. The experimental parameters for both acquisitions were identical: T_p=120μs, T_R=10ms, FOV=20x20x20mm, resolution 64x64x16 points, α=6° RF pulse, 1 average, and for SPI/VTI a phase encoding interval of t_p=<40-120μs>. The reconstructed images are shown in Fig.5 and reveal that SPI/VTI acquisitions have ~3.6 higher SNR. The comparison of the integrate details from both images shows that the filtering effect of T^*_2 related signal variation for SPI/VTI is observable but not crucial. Another consideration for SPI/VTI is a possible increase in susceptibility artifacts because of the non-constant T_P. The phantom experiment in presence of an air-bubble indicates that SPI/VTI is still resistant to eventual inhomogeneities of the main magnetic field (Fig. 6).

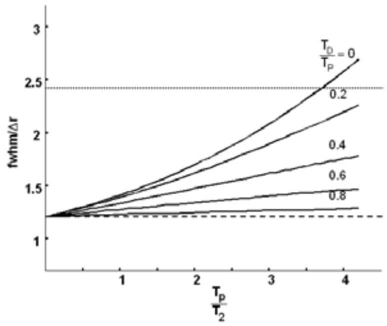

Fig.4 LSF calculated as full width at half maximum (fwhm) for the SPI/VTI and different ratios of T_D/T_p and T_p/T2. The dashed line represents the ultimate SPI/CTI resolution, which is 1.21·Δr and the dotted is double of this resolution.

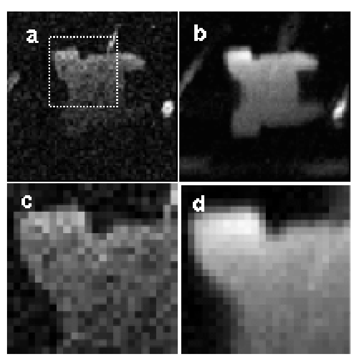

Fig.5 Images of a rubber stopper obtained with SPI/CTI (a) and SPI/VTI. (b). The finer details from the edge of the stopper is zoomed and shown for both types of acquisitions in (c) and (d).

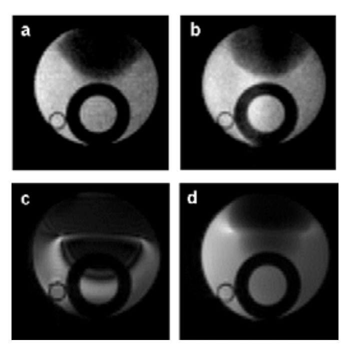

Fig.6 (a) 3D-SPI, T_p=270 us, TR=10 ms, (b) 3D-SPI/VTI, t_p=〈30-270 us 〉, TR=10 ms, (c) 3D gradient-echo, echo time=4 ms, TR=40 ms, (c) 3D spin-echo TE=15ms, TR=1000ms.

References: [1] S. Gravina, D.G. Cory, *J. Magn. Reson.* **B 104**, 53-61 (1994), [2] M. D. Robson, D. J. Tyler, S Neubauer, MRM, **53**, 267–274 (2005), [3] P.Latta, M.Gruwel, E.Edie, M.Sramek,B.Tomanek, *J. Magn. Reson.* **170***,* 177-183,(2004).