Measurement of T2 of an ROI of arbitrary shape using spatially selective excitation

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Introduction:

There are several potential advantages to being able to measure NMR properties such as T_2 for regions of interest (ROIs) of arbitrary shape. Such measurements may estimate tissue characteristics with higher signal to noise ratio (SNR) and the ROI can itself be chosen using imaging features rather than subjective outlines. In particular, measurements of multi-exponential transverse decay curves require both high SNR and short echo spacing, and are usually obtained by acquiring multi-echo datasets for the entire image. An ROI is then selected from the image and T_2 spectra are calculated, but this process takes a long time and results in relatively low SNR due to the necessary small voxel sizes. Here is presented a new protocol for making quantitative T_2 measurements for arbitrarily shaped ROIs using interleaved spatially selective excitation pulses combined with a CPMG echo acquisition. This novel technique acquires signals from the entire ROI as a single voxel by encoding in the excitation phase rather than after acquisition. The corresponding SNR is proportional to the ROI area and square root of (Numbers of interleaves (N_i) * Number of acquisitions averaged (NEX) / Bandwidth). Typical ROIs in vivo may be 10s to 100s of times larger than a voxel, which would provide a significant improvement in accuracy of characterizing decay curves from tissues. Phantom experiments have been conducted and are presented.

Theory and Methods:

Extending the approach introduced by Pauly et al. [1], interleaved spatially selective excitation pulses were generated by discrete Fourier transformation of the arbitrary shape 2D ROI which was defined manually from a scout image. A constant-angular-velocity spiral K-space trajectory for excitation was chosen primarily because of its low demand on RF peak power, as demonstrated by Qin et al. [2]. A series of interleaves shortens the excitation pulses to avoid both the blurring effect of the target ROI from field inhomogeneities and signal loss of short T_2 components inside the ROI. The relative phases of the transverse magnetization between each interleaved excitation are preserved by the CPMG 180 pulses surrounded by appropriate spoiler gradients [3]. The echo magnitudes of all the recorded echoes at the same echo time from each interleaved excitation of the ROI were summed. Fig. 1 shows the pulse diagram of one interleave. A sinc shaped slice selective refocusing pulse followed after the interleaved excitation pulse. Composite 180 pulses ($90_x180_y90_x$) were used for CPMG refocusing.

The experiments were conducted on a Varian 9.4T 21cm bore scanner. To mimic the fine resolution in rat brains, a phantom was made that was composed of 1mm-diameter tubing filled with $MnCl_2$ with T_2=26ms, surrounded by $MnCl_2$ with T_2=52ms as the bath. A conventional single slice multi-echo imaging protocol was used to compare measurements with our new technique. The FOV was 25.6mm and 64 by 64 matrix was imaged with 2mm slice thickness. The voxel size was 0.16mm^2. We used 24 echoes and 10ms echo spacing. TR was 3s with 2 NEX and 2 dummy scans making the imaging time about 6.4minutes. The bandwidth was 100Khz. Two ROIs were chosen, one including only the tubing (7mm^2), another one including only the bath region (18mm^2). Our spatially selective technique used 4 interleaves and 4us dwell time and subsequently each excitation pulse length was about 6.5ms. Then the interleaved gradients and corresponding weighted RF pulses were calculated based on the selected ROIs. The RF power was adjusted to give a roughly 45 degree flip angle excitation to avoid significant non-linearities in excitation. The multi-echo measurement kept the same parameters used by imaging method except that the bandwidth was reduced to 25Khz. Accordingly our technique only used 0.8minutes, 1/8 of the imaging method. For each echo of any interleaved excitation, 16 complex points were recorded, centered on each echo.

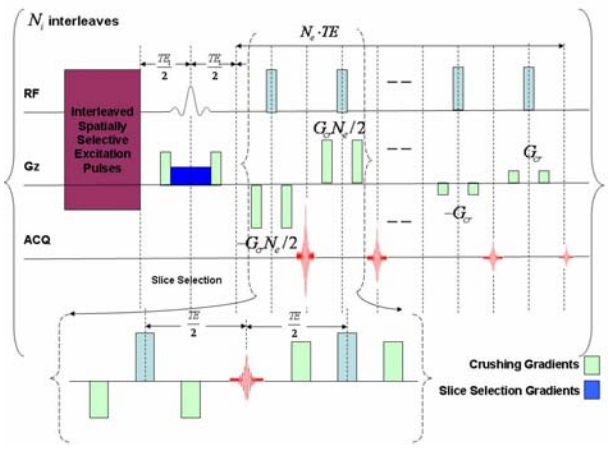
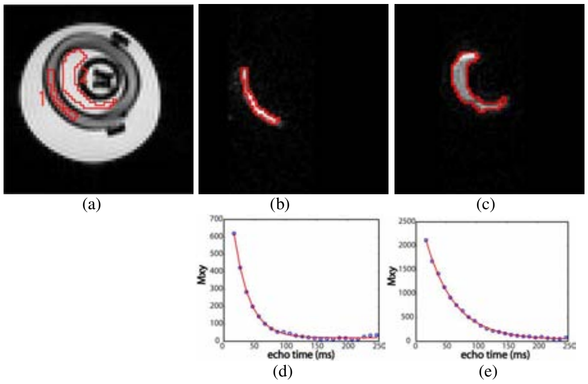


Fig. 1: Pulse diagram of T_2 measurement from arbitrary shape ROI using interleaved spatially selective excitation pulses.



(a) (b) (c)

(d) (e)

Fig. 2: (a) phantom with 2 ROIs;.(b) ROI 1 excited profile; (c) ROI 2 excited profile; (d) T_2 curve from ROI 1; (e) T_2 curve from ROI 2.

Table 1. Measured T2s of ROI 1 and 2 from two methods

	ROI 1: T_2	ROI 2: T_2
standard multi-echo imaging	26 (ms)	52 (ms)
Interleaved spatially excitation	25 (ms)	49 (ms)

Results and Discussion:

Both imaged excitation profiles of the two ROIs and the corresponding T_2 measurements are displayed in Fig. 2. The scout image of the phantom is shown in Fig. 2 (a). ROI 1 (tubing, 26ms T_2) and ROI 2 (bath, 52ms T_2) are prescribed by the red lines. Fig. 2 (b) (c) are the summed image results of 4 interleaved excitation of these two selected ROIs. Fig. 2 (d) (e) are the measured T_2 curves, with the circles as the summed echo magnitudes from 4 interleaves and red lines as the fit of the mono-exponential model. The fitted T_2 values of both ROIs using our method are shown in table 1 and are comparable to the results using imaging method. The SNR per unit time is higher using the spatially selective method than conventional imaging.

Conclusion:

These experiments demonstrated the feasibility of making quantitative measurement of T_2 relaxation from ROIs of arbitrary shapes using interleaved spatially selective excitation methods.

References:

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