Potential Sources for MR Signal Delay

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INTRODUCTION

MR signal (or free induction decay, FID) is sometimes delayed in time after a short RF excitation, compared with its normal (non-delayed) exponential T_2* decay. This phenomenon was observed by us and firstly reported at the ISMRM annual meeting in 2009 (1). The signal delay might be a useful mechanism for developing new MRI measurements. However, the reason for this is not clear at this stage. Some consider the delay as artifacts from gradient dephasing, B_0-field inhomogeneity, susceptibility effect, data acquisition distortion, blurring of point spread function, or chemical shift. We instead considered it as a real phenomenon and hypothesized that the delay might be caused by B_1-field delay due to micro eddy currents built-up by mobile ions in tissue. In this work we investigate potential sources of MR signal delay through computer simulations and phantom experiments.

SIMULATIONS AND EXPERIMENTS

Simulations Three most-likely sources (gradient dephasing, B_0-field inhomogeneity and chemical shift) were investigated by establishing off-resonance frequency distributions in a voxel, *p*(*f*), for each of these cases (Tab. 1). The MR signal from the voxel is the summation of spins processing at all frequencies in the voxel. The B_1-field delay was simulated by adding an exponential decay of time constant τ_{b1}. This delay leads to a delay in flip angle and thus a delay in MR signal (Tab. 1). ***Experiments*** Phantoms (plastic bottles) were filled with NaCl water (distilled) solution of NaCl concentrations of 0, 250, 500, 750, and 1000 mM, respectively. MRI scans on the phantoms were performed on a whole-body 3T scanner (Magnetom Trio Tim, Siemens Medical Solutions, Erlangen, Germany) with Tim head coil, using a home-developed UTE sequence, the acquisition-weighted stack of spirals (AWSOS) (2), with acquisition parameters: TR=80ms, TE=0.6-50ms, θ=15°, and rectangular RF duration=0.8ms. slices=60 at thickness 3mm, FOV=220mm, matrix size=256, in-plane spirals=24 at readout Ts=7.84ms.

Tab. 1. Distribution of off-resonance frequencies at a voxel, and RF delay

Cases	*p(f)*
Gradient dephasing	$rect\,(f/\Delta f)$
B_0-field inhomogeneity (Lorentzian)	$2\Delta f/[(\Delta f)^2+(2\pi f)^2]$
B_0-field inhomogeneity (Gaussian)	$N(0,\Delta f)$
Chemical shift (two components)	$a_1\delta(f)+a_2\delta(f-\Delta f)$
B_1-field delay (rectangular RF)	$B_1(t)=rect(t/\tau)+\exp(-t/\tau_{b1})\otimes[\delta(t-0.5\tau)+\delta(t+0.5\tau)]$
Flip angle delay	$\theta(t)=\gamma\int B_1(\xi)d\xi$
MR signal delay	$s(t)=M_0\sin[\theta(t)]+u(t-\tau/2)\cdot M_0\sin[\theta(\tau/2)]\exp[-(t-\tau/2)/T_2*]$

RESULTS AND DISCUSSION

Results The simulated signals in the presence of gradient dephasing, B_0-field inhomogeneity and chemical shift show that non of these three produced a delay in MR signal (Fig. 1). RF delay, on the other hand, resulted in MR signal delay (Fig. 2a). When an exponential decay due to micro eddy currents was added into a rectangular RF, the resultant RF was delayed (Fig. 2b), and the MR signal was accordingly delayed (Fig. 2c). Phantom experiments showed that the delay time of MR signal is linearly increasing with the concentration of NaCl (Fig. 3a-c), and there was no delay at 0.0 concentration of NaCl. ***Discussion*** The simulated results showed evidence that MR signal delay was not an artifact from imperfect performance of the MRI system. Instead, it was a new phenomenon. The simulations also supported that RF (B_1-field) delay had potential to produce MR signal delay. The phantom experiments have confirmed this hypothesis. It also showed that mobile ions in the solution had electromagnetic (EM) interaction with primary B_1-field and generated micro eddy currents that were against the change the primary B_1-field and thus resulted in a delay in the resultant B_1-field. **In conclusion**, this work has demonstrated that MR signal delay is a real phenomenon and caused by RF (B_1-field) delay due to the EM interaction via micro eddy currents generated by mobile ions. The delay time was related to mobile ion concentration.

REFERENCES: [1] Qian Y, etc. ISMRM 2009; p# 2979. [2] Qian Y, etc. US patent 7,750,632. 2010.

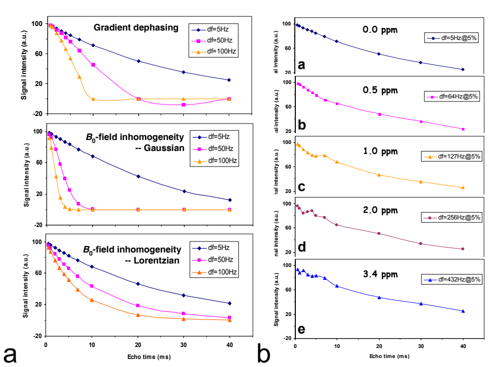

Fig. 1. Simulated signals in presence of gradient dephasing and B0-field inhomogeneity (a) and chemical shift (b). No signal delay was found.

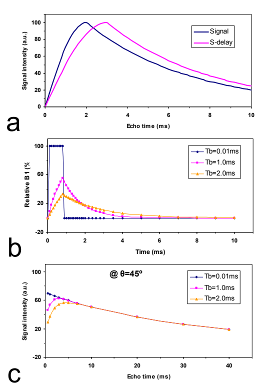

Fig. 2. Simulated signal delay (a), RF delay (b), and signal delay after RF excitation (c).

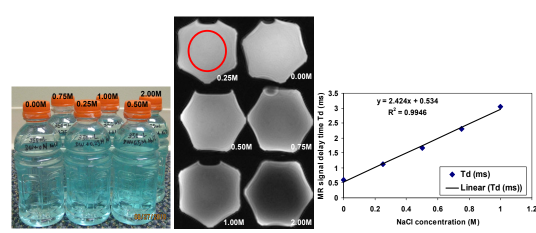

Fig. 3. Phantom experiemental results: phantoms (a), MRI images (b) and measured delay time (c). The measured signal delay time linearly increases with the concentration of NaCl in the phantom increasing.