On the Effectiveness of RF Spoiling at 7T

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Mapping RF magnetic fields at 7T is essential for accurate adjustment of transmitter gain [1] as well as for the design of compensating pulses to generate more uniform flip angles [2]. Actual Flip Imaging (AFI) [3] has emerged as a fairly straightforward method for B_1 field mapping but is challenged at 7T by the longer T_1 values fond in many tissues [4] as well as the range of variation in B_1 across a typical subject or phantom. AFI relies on the establishment of a spoiled steady-state [5], and both T_1 elongation and significant B_1 variation impact the generation of such a steady-state. The following investigates these effects through simulation, phantom, and volunteer strudies.

Simulation Methods

A matrix approach was taken to simplify the simulation using scripts developed by Hargreaves [6]. Magnetization from a set of 100 isochromats at frequency offsets from -1/(2TR) to 1/(2TR) (leading to 2π dephasing over TR) were separately calculated and then combined to produce the equivalent signal at the chosen echo time. Quadratic phase shifts with 181 seed values from 0 to 180 degrees were applied for each iteration, and 100 iterations were performed to establish a steady state, regardless of the chosen repetition time (greater numbers of iterations were not found to alter the results even at the shortest repetition times). Scripts were executed in Octave 3.2.3 on a MacBook Pro in less than 2 minutes per run. The steady state signal was then calculated as the transverse portion of the magnetization after 100 iterations for each seed value and sequence timing and flip angle condition.

Phantom and Volunteer Methods

A multiphase fast gradient echo pulse sequence (fgre) was modified to adjust the quadratic phase increment for each image from a prescribed starting point. For the shortest repetition time (7.5 ms), the starting point was 0 degrees, while for longer repetition times the starting point was 80 degrees. An increment of 1 degree was used throughout. Various excitation pulse flip angles were chosen, and data was acquired in mid-axial or mid-sagittal planes through a 17 cm diameter spherical phantom containing either doped water or doped polydimethylsiloxane, with a previously measured T_1 at 7T of roughly 600 ms. Data were acquired using a Nova Medical (Wilmington, MA) 2 channel transmitter with 8 channel receiver on a GE 7T Human MR Research Imaging System (Waukesha, WI). Volunteer scanning was performed under informed consent with a protocol approved by the UCSF Committee on Human Research using similar acquisition parameters.

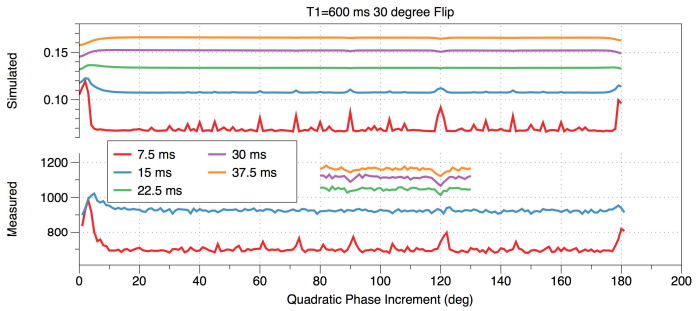
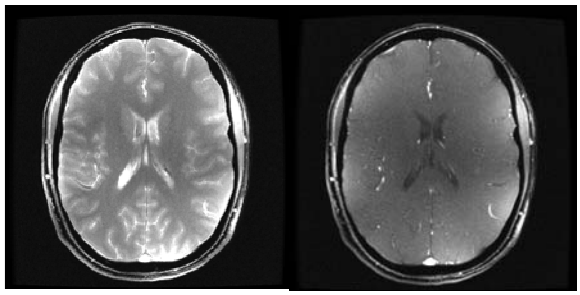


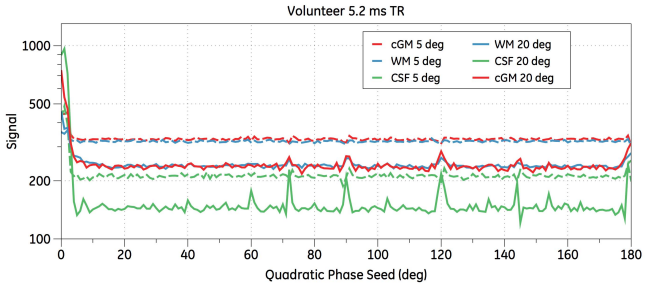
Image Analysis Methods

Images were reconstructed on the console using standard reconstruction methods with weak Fermi filtering and in plane geometry correction. Regions of interest in magnitude images were selected interactively and plots generated for the corresponding pixels in subsequent images (with different phase seeds) were extracted.



Discussion and Conclusions

Phantom and simulation data are shown above right. General agreement is demonstrated between the simulation and phantom data with regard to the dependence on repetition time and phase increment, and residual effects of B_0 inhomogeneity appear to be minimal. In general, the size of the enhancement is reduced compared to the simulations. Volunteer data (above right) for a 5 degree nominal flip angle shows very little enhancement away from 0 degree phase increment at low flip angles (unbalanced steady state free precession), except for the slight shift in the peak in CSF noted previously [7]. Blood vessels remain bright due to inflow. The time course plots for CSF, white matter, and cortical grey matter at 5 degrees show very little enhancement for any nonzero phase increment, while significant enhancement is shown for CSF at a larger nominal flip angle. This flip angle spoiling dependence must be considered in analysis of AFI data at 7T.



References:

[1] Collins & Smith MRM 2001 45:684-691 [2] Grissom et al MRM 2006 56:620-9 [3]Yarnakh MRM 2007 57:192-200 [4] Rooney et al MRM 2007 57:308-318 [5] Nehrke MRM 2009 61:84-92 [6] Hargreaves http://mrsrl.stanford.edu/~brian/bloch [7] Duyn MRM 1997 37:559-568.