Simulation of sequence-specific signal variation due to B_1 inhomogeneity at 7T

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Introduction: The effect of flip-angle variation due to higher radiofrequency (RF) and B_1 inhomogeneity at 7 Tesla [1] is highly sequence specific. This project investigates methods of compensating for B_1 inhomogeneity in the case of a single transmit channel. A simulation tool has been developed to show the effect of flip-angle variation with different sequence types. Simulation results are compared with real images of phantoms.

Methods: A homogeneous human head phantom (40.3% water, 58.3% sucrose, 1.24%NaCl, 0.08% preservative and measured T_1=449ms) was imaged using a commercial 7-Tesla MRI system (Magnetom Terra, Siemens Healthineers, Erlangen, Germany) and a single-channel-transmit, 32-channel-receive head coil (Nova Medical, Wilmington, MA, USA). B_1 maps were measured using a sequence provided by the manufacturer of the scanner. A gradient-echo (GRE) image was acquired with: TR=1000ms, TE=2.6ms, slice thickness=6.5mm, matrix size=64×64, flip-angle =60°. The B_1 map was used to generate a simulated GRE image, which was calculated in MATLAB (MathWorks, Natick, MA, USA). To provide a quantitative comparison between simulated and measured images, a percentage difference map was generated, in which pixels corresponding to a 90° flip angle in the B_1 map were scaled to the same pixel value. For other flip angles, positive values in this map correspond to pixel locations for which the measured image has a higher signal than the corresponding simulated image.

Results: The real GRE image that was measured is displayed in figure 1. The simulated image and the scaled difference map are shown in the figures 2 and 3 respectively.

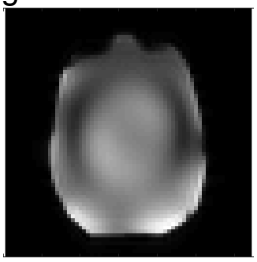

figure1: real GRE map

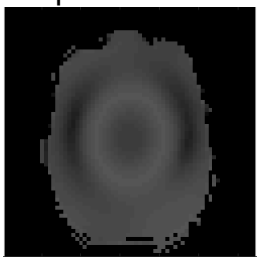

figure2: simulation image

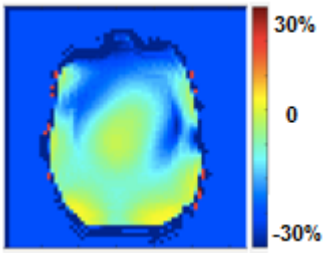

figure3: difference map

Discussion: The simulations provided a good indication of the signal variation in the measured images. However, as seen in the difference map, there is a residual difference between real and simulated images, which requires further investigation. This difference is probably caused by effects, such as slice profile, that have not yet been considered in the simulation. It is also important to confirm the reliability of the measured flip angles provided by the B_1-mapping sequence. Further work is underway to extend these studies to the investigation of other sequence types and to modify the signal model used in the simulations to provide a closer agreement to the measured signal variation. In particular, it will be important to investigate the behaviour of multi-shot RARE sequences, which are clinically important, but currently have limited diagnostic use at 7 T due to signal variation in inferior brain regions.

Conclusion: This work has shown that simulations based on measured B_1 values can provide a good prediction and understanding of the associated sequence-specific signal variations in measured images. This approach will be used in future work to investigate how changes to pulse sequences and measurement protocols can be used to mitigate the effect of B_1 inhomogeneity when using single-channel-transmit MRI systems at 7 Tesla.

Reference: [1] Vaughan JT, Garwood M, Collins CM, et al. 7T vs. 4T: RF power, homogeneity, and signal-to-noise comparison in head images. Magn Reson Med. 2001;46:24–30