Improving SNR and Spatial Coverage for 7T DTI of Human Brain Tumor Using B1 Mapping and Multiband Acquisition

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Target Audience: Pulse sequence designers, neuroscientists, and neuroradiologists working on 7 Tesla human MR systems

Purpose: Off-resonance effects, shorter T2 values and RF inhomogeneity have limited the ability to perform accurate diffusion tensor imaging at ultra-high field. Although these obstacles can be partially mitigated using parallel acquisition [1] and readout-segmented EPI [2] techniques, image quality is insufficient for performing high quality research studies of patients with brain pathology. As a result, it is frequently necessary to obtain both 3T and 7T scans to enjoy the benefits of 7T for anatomic imaging and simultaneously obtain diagnostic DTI data. In this work, we employ B1 mapping to automatically adjust transmitter gain and multiband acquisition to further improve the quality of 7T DTI, and demonstrate the application of these techniques to healthy volunteers and in a patient with a brain tumor.

Methods: Subjects were imaged using both a GE Signa HDxt 3T system (GE Healthcare, Waukesha WI) and a GE Signa Discovery MR950 7T system (GE Healthcare, Waukesha WI) under a protocol approved by the Committee on Human Research with informed consent. 3T diffusion images were acquired with 3 mm slice thickness, 25 slices, 8.67 mm^3 voxels, 6 directions, b=1000 s/mm2, TE/TR 87/7000 ms, 4 avg, 3:23 scan time, R=2 ASSET. At 7T, diffusion images were acquired using a 2 channel transmit/32 channel receive head coil (Nova Medical, Wilmington, MA) using ARC parallel acquisition [3] with 8 mm^3 isotropic voxels, TE/TR 60/3500, 15 directions, 63 slices with b=2000 s/mm^2, 2 avg, 2:34 scan time, R=3 ARC and 2 methodological improvements:

- *Improved transmitter gain optimization.* B1 maps were generated using gradient echo acquisition (TR/TE=250/8 ms) with a 1 ms adiabatic Bloch-Siegert pulse [4]. Based on the resulting B1 map and the peak B1 field strengths required for the excitation and refocusing pulses in the diffusion sequence, an estimate of the spin echo signal neglecting saturation effects (assuming a long repetition time) was calculated. The integrated spin echo signal was calculated for each slice as a function of transmitter gain, and the transmitter gain required to generate the maximum integrated signal was estimated. This transmitter gain value was used for the diffusion acquisition.
- *Multiband excitation.* Multiband separation [5,6] was performed using 3D ARC kernel using coefficients derived from 3 calibration images which had different phase offsets applied to each band and were fully sampled in-plane. Homodyne reconstruction was applied to generate complex-valued images for each channel, which were then combined by root sum of squares.

Results: Figure 1 shows calculated spin echo signal in one slice for different values of transmitter gain, and Figure 2 illustrates representative b=0 images for the patient that were obtained using the optimal transmitter gain. Calculated maps of fractional anisotropy are shown in Figure 3 and overlaid on the b=0 images in Figure 4. Comparable images from 3T are shown in Figure 5. On subjective review of the 3T and 7T diffusion images by a subspeciality-certified neuroradiologist, the 7T images were considered diagnostically equivalent to the 3T images.

Discussion: Two practical hurdles limit the quality of diffusion images obtained at 7T. First, the reduction in T2 and the greater B0 inhomogeneity at higher field strength result in significantly lower T2*, such that that for a fixed TE there is less available signal at 7T than 3T. This decline can completely offset the higher static magnetization at 7T compared to 3T, and thereby obviate the SNR advantages of ultra-high field. Second, due to B_1 inhomogeneity, obtaining a true spin echo over the entire brain has not been possible at 7T, further reducing the available signal. By incorporating the measured B1 field strength, the situation was improved, providing 82% of the available spin echo signal. Improved parallel imaging methods and the use of higher acceleration enabled by higher field strength allow a significant reduction in echo time, and the use of multiband acquisition allows more slices to be acquired for the same scan time, improving the spatial coverage.

Conclusions: Integrating B_1-map-based automated selection of transmitter gain and multiband acquisition with parallel acquisition improves the quality of diffusion imaging at 7T as well as the spatial coverage.

References: **1**. Speck et al. MAGA 2008 21:73-86 **2**. Heidemann et al. MRM 2010 64:9-14 **3**. Beatty ISMRM 2007 #1749 4. Khalighi et al MRM 2012 in press **5**. Moeller et al. MRM 2009 63:1144-53 **6**. Setsompop et al. Neuroimage 2012 63:569-80.