Practical Vector B1 Mapping at 7T

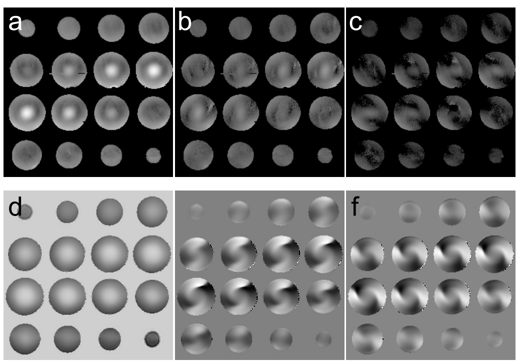
D. Kelley[1,2], and J. Lupo[2]
[1]Applied Science Laboratory, GE Healthcare, San Francisco, California, United States, [2]Radiology and Biomedical Imaging, University of California, San Francisco, San Francisco, California, United States

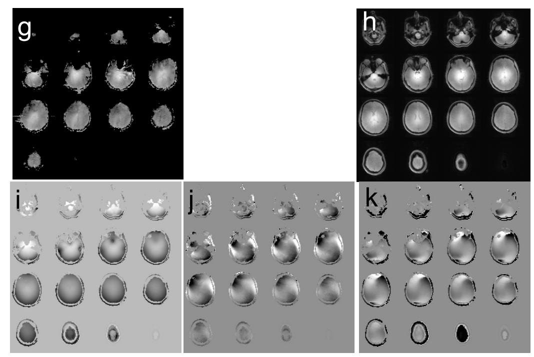
<u>Introduction</u> Compensation for B_1 inhomogeneity at 300 MHz relies on a detailed knowledge of the magnitude and phase of the B1 fields generated by each transmit coil element. Prominent concerns in implementing such measurements are overcoming sensitivity to long T1 relaxation times at 7T without lengthy acquisition times, reducing sensitivity to slice profile variations in multipulse sequences, and providing a suitable reference for transmit phase measurements. The following method provides a reliable method for making these measurements in phantoms and volunteers which can be practically integrated into a research protocol. Typical data quality is shown in phantoms and volunteers.

<u>Methods</u> Phantom and volunteer studies were performed on a GE 7T human research system (GE Healthcare, Waukesha WI) using a 2 channel transmitter coil with an 8 channel receiver array (Nova Medical, Wilmington MA) present but detuned electronically. The transmitter coil was used both as a transmitter and receiver. All human studies were performed under IRB approval with informed consent.

B_1 magnitude was mapped using a variation on the double angle method [1,2]. Multishot gradient recalled echo planar images were acquired with 5 mm slice thickness and a 5 mm gap over the volume of interest at two nominal flip angles (30 and 60 degrees) with a 15 second repetition time on a 64 by 64 matrix with a 20 cm field of view. Four shots were acquired for a total acquisition time of 1 minute per flip angle. An additional acquisition was performed at 60 degrees without phase encoding gradients to provide a phase correction reference for the EPI reconstruction. Images were reconstructed using a nonlinear phase correction procedure similar to [3], and data from the two receiver channels were combined by root sum of squares after resampling to compensate for ramp sampling. A threshold mask was generated using the 60 degree images, and within the masked region the B_1 was calculated as the arc cosine of half the ratio of the intensities of the two images. The procedure was repeated twice with the individual transmit channels disabled.

B1 phase was calculated from three volume gradient echo datasets, one acquired with the two transmit channels in a nominal circularly polarized configuration, and then by subsequently disabling the individual transmitter channels. A 64 by 64 by 64 matrix was used over





a 20 cm field of view with 3.125 mm slice thickness (to give isotropic voxels). The echo time was 2 ms with a 32 kHz receiver bandwidth and a 15 ms repetition time, with a nominal flip angle of 30 degrees. The volume datasets were reconstructed offline to produce complex images using software developed by the author. Phase maps were generated and unwrapped using the method of Cline [4] and then combined by weighting the individual data by the ratio of the squared magnitude of each channel to the sum of squares of all channels. The resulting CP phase map was then subtracted from each of the corresponding single channel maps to give the phase of each individual channel. The images were then resampled to match the EPI dataset using bandlimited Fourier interpolation [www.itk.org].

<u>Results</u>

Phantom results for a doped water phantom [5] are shown above left; in vivo results are shown above right. For the phantom data, a shows the circularly polarized B_1 and the individual channel maps are shown in b and c. The contributions for the two channels are not equal in the phantom due to the performance of the coil. The phase map for the circularly polarized data set (including transmit phase, receive phase, and B0 variation) is shown in d; e and f show the net phases for the individual transmit channels. The patterns are essentially identical after a 90 degree physical rotation. Volunteer data is shown above right. The CP B_1 map is shown in g, with the resampled 3D magnitude images in h. The CP phase reference data is shown in i, with the net transmit phases in j and k. All B_1 maps are displayed at a common window and level; phase maps are displayed at appropriate window and level to show structure.

<u>Discussion</u>

The in vivo data reveals the complexity of the problem at 7T. While the phase patterns are similar, the asymmetry of the object is visible in the differences between the phase patterns. A further point is that the phase difference between these two patterns is clearly spatially varying, introducing a loss of efficiency for a single static phase difference (as with the use of a quadrature hybrid or a B1 shimming approach).

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<u>References</u>[1]Insko and Bollinger JMR A, 103, 82-85, 1993. [2] Stollberger and Wach MRM 35, 246-51, 1996. [3] Schmitt in **Echo Planar Imaging** New York:Springer, 1998 [4] Cline et al. MRM 51 1129-37, 1996 [5] Schirmer and Auer NiB 13, 28-36, 2000.