Statistical Analysis of in vivo B1 Maps at 7T

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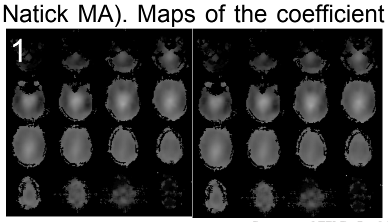
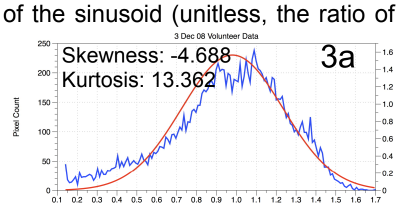
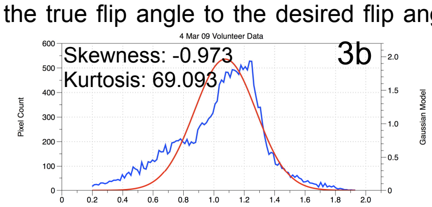
Introduction Development of compensation schemes for B_1 variation in human subjects at 7 Tesla must be based on a clear estimate of the degree of B_1 variation that must be corrected. Additionally knowledge of the statistical nature of the distribution can facilitate the assessment of different correction schemes. While computation of the fields can provide indications of the degree of variation, the field distribution depends critically on the distribution of material properties (conductivity and permittivity) which are not easily measured. Several groups [1] have reported field variations as standard deviations, which would not adequately capture the degree of variation for non-Gaussian distributions. The following describes a retrospective assessment of B_1 field maps acquired in several subjects over several months to determine the range of B_1 variation, and the extent to which the distribution is Gaussian.

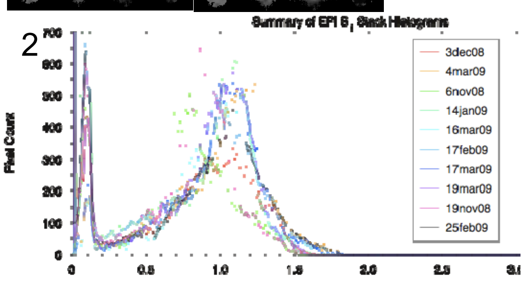
Methods All studies were performed on a 7T human research system (GE Healthcare, Waukesha WI) using a 2 channel head transmitter coil (Nova Medical, Wilmington, MA). Human studies were performed on normal volunteers with informed consent under a protocol approved by the Committee for Human Research. B1 field maps were collected from 10 individuals using a 4 shot gradient recalled echo planar imaging sequence with a 15 second repetition time, for an acquisition time of 1 minute per flip angle. 6 such acquisitions were made in each volunteer, at flip angles of 10 degrees, 15 degrees, 30 degrees, 60 degrees, and 75 degrees, with the 60 degree flip angle repeated without phase encoding gradients to provide a phase reference. Raw data were transferred off line for reconstruction.

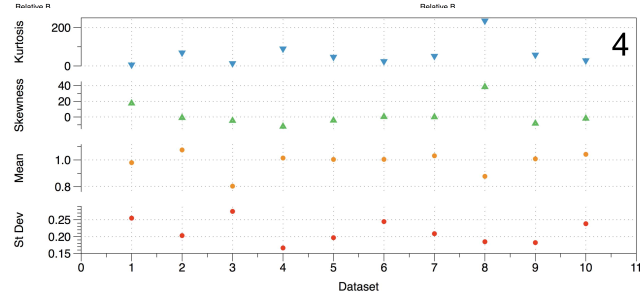
A nonlinear phase correction scheme was employed for each channel's data [2], followed by root sum of squares combination to produce the final magnitude images. A binary threshold mask was constructed from the 60 degree data, and all points within the mask for the 5 flip angles for each subject were fit by a Trust Region nonlinear least squares fit to a single sinusoid using Matlab (Mathworks, Natick MA). Maps of the coefficient of the argument of the sinusoid (unitless, the ratio of the true flip angle to the desired flip angle)











were then generated. B_1 maps

were then inspected visually and the range of values over the brain were measured. Histograms of these values were then analyzed as follows.

The low amplitude values in the histogram represent noise and were excluded from further analysis. The cumulative probability was calculated as the ratio of the cumulative pixel count to the total pixel count, and an equivalent Gaussian distribution was generated based on this cumulative probability. The mean and standard deviation were interpolated from the resulting Z scores, and the skewness and kurtosis were calculated based on these values. For a Gaussian distribution, the skewness should be 0 and the kurtosis should be 3 [3].

Results B1 maps from two representative individuals are shown below in Figure 1. The stack histograms of all the B1 maps are shown in Figure 2. Representative Gaussian fits are shown for the two representative studies in Figures 3a and 3b, and the range of values of values over all 10 subjects are shown in Figure 4. While 3a shows a somewhat Gaussian fit, Figure 3b clearly shows a poor fit.

Discussion The range of B_1 enhancement in all subjects is roughly 3 fold, from 0.5 to 1.5, which places definite constraints on the utility of adiabatic RF pulses many applications -- to cover so broad a range, higher sweep rates and higher peak and average power levels are required than at lower field strengths. While there is some variation from subject to subject the minima and maxima are fairly consistent, although larger studies will be required to validate this assessment. Finally, the distribution of B_1 values is distinctly non-Gaussian, with long tails to both sides of the mean, revealed by the high kurtosis values (mean across subjects is 62.183). For a spherical phantom, one would expect a (sum of) spherical Bessel functions [4], which are distinctly non-Gaussian in character, and the fields inside a head are similarly distributed. Robust field mapping across subjects has been demonstrated, allowing intersubject comparison, revealing several common features of the maps.

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References [1] Setsompop, et al. MRM 60, pp 1422-32, 2008. [2] Schmitt in Schmitt, Stehling, Turner **Echo Planar Imaging** New York:Springer, 1998 [3] *NIST/SEMATECH e-Handbook of Statistical Methods*, http://www.itl.nist.gov/div898/handbook/, 8 November 2009 [4] Cline et al. MRM 51 1129-37, 1996