Effects of Material Outside the FOV on Magnetic Field Uniformity

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ABSTRACT: To improve image quality in human brain fMRI studies, a study of the magnetic field perturbation patterns generated by human subjects was undertaken. The resulting statistics showed a high degree of variability and no common features could be found in the human population. However, it was found that distortion components that were most variable in the human population corresponded to components generated by a torso phantom, implying that the variability in magnetic field perturbations in the human population comes from material outside the FOV.

INTRODUCTION: To reduce magnetic field non-uniformities, hardware must be designed to correct magnetic field perturbations generated by subjects when they are placed in a scanner's imaging volume. To optimally correct magnetic field perturbations generated by human subjects, it would be useful to determine if there are common features in perturbations generated by all members of the human population, and target hardware design to correct these common perturbations.

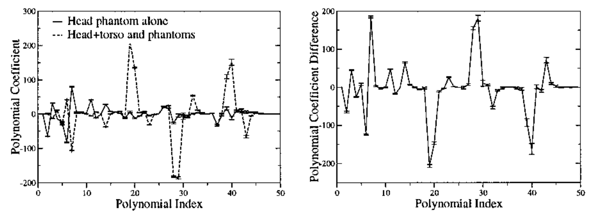
The set of spherical harmonic polynomials is the basis set to which spatial patterns in magnetic field perturbations are decomposed. In this study, the first 49 polynomials of this set are used, which allows analysis of up to 6^{th} order spatial variations in magnetic field perturbations.

METHODS: The hardware used was a Bruker Biospec 30/60 3T MR scanner, equipped with a local head-gradient coil and an end-capped birdcage RF coil. Magnetic field maps were collected using a dual-TE gradient echo sequence with parameters: TR = 900 ms, TE = 15 ms, ΔTE = 1 ms, BW = 31.25 kHz, image matrix = 32 $\times$ 32, 29 slices, slice thickness = 6 mm, slice separation = 6.25 mm, FOV = 200 mm. These are the same parameters used for the autoshimming protocol developed for this scanner (1). This protocol optimizes magnetic field uniformity by calculating optimal current values for 14 shim coils. Magnetic field maps from 354 subjects were collected using the same parameter values, after the autoshimming protocol was performed.

For the phantom studies, a plexiglas cylinder (165 mm diameter, 122 mm height) filled with a 0.0938M NaCl/0.005M $CuSO_4$ solution served as the head phantom. It was scanned with and without a 20-liter polyethylene bottle (the torso phantom) containing the same solution placed, so that its "neck" rested against the head phantom.

All field maps were decomposed into 49 spherical harmonic polynomials using a Singular Value Decomposition algorithm. The origin of the coordinate system used for the spherical harmonic polynomials was the center of the FOV, and all polynomial components were evaluated only in regions where the signal was above 10% of the maximum in the FOV. For the human population, average and standard deviation values were calculated. For the phantom data, corresponding statistics were calculated. For the two phantom arrangements (acquiring the magnetic field maps with and without the torso phantom), the difference in corresponding coefficient averages was also calculated.

RESULTS:



(a) (b)

Figure 1: (a) Distributions from phantom arrangements (b) Difference in distributions (due to torso phantom)

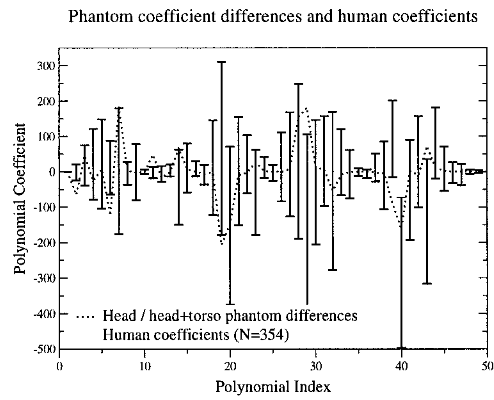


Figure 2: Coefficients due to torso phantom compared to coefficient variation in human population

DISCUSSION: The spherical harmonic polynomials that showed the largest change when the torso phantom was added are also the most variable in the human subject population. These are polynomials #19 ($z^3y - 0.75zyR^2$), #20 ($(z^2 - R^2/6)(x^2 - y^2)$), #28 ($z^4y - 1.5z^2yR^2 + 0.125yR^4$), #29 ($(z^3 - 0.5zR^2)(x^2 - y^2)$), #32 ($(z^2 - 0.125R^2)(3x^2y - y^3)$), #40 ($(z^4 - z^2R^2 + 0.0625R^4)(x^2 - y^2)$), #43 ($(z^3 - 0.375zR^2)(3x^2y - y^3)$), where $R^2 = x^2 + y^2$. Hardware to compensate for magnetic field perturbations in human brain studies should be able to correct these polynomials as they seem to be the most variable. The results indicate the variability seen in magnetic field perturbation patterns in humans originate from susceptibility effects of materials outside the field of view, previously suggested by Yetkin et al. (2).

REFERENCES:

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2. Yetkin, F. Z. et al. *AJNR* **17**, 1005-1009, 1996.