Transmit Field Estimation from K-space Data

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Target Audience: Researchers and clinical practitioners specialized in MR imaging processing.

PURPOSE: Imaging of large objects at high field generally introduces large signal inhomogeneity associated with wavelength effect, object configuration and object electromagnetic properties. Estimating transmit field B_1^+ maps is prerequisite for various techniques (such as RF shimming, parallel excitation and inhomogeneity correction) to mitigate signal inhomogeneity, quantitative MR imaging and electrical property mapping. The status quo gold standard utilizes pixel-wise division which could be problematic when the image SNR is low. Here we explored the feasibility of estimating B_1^+ maps accurately, rapidly and robustly in k-space domain using a convolution kernel.

METHOD: Conventional B_1^+ mapping methods estimate B_1^+ maps by processing phase and magnitude of a set of images in image domain. Various factors, such as scan time, reliability, accuracy and limit their applications in research and clinic settings. Few method estimates relative B_1^+ maps using k-space data [1]. Here we propose a k-space approach to estimate B_1^+ maps in double flip-angle method, eliminating the pixel-wise division completely. It estimate a k-space convolution kernel c(k) between two k-space of image A and B: $F(A) = F(B) \otimes c(k)$. Convolution kernel c(k) can be calculated using k-space data fitting method, exactly the same as the kernel estimation in GRAPPA/SPIRiT algorithm. Since transmission field is independent of the receive sensitivity, the proposed method can utilize a single channel in a phased-array coil to estimate the transmission field. Every k-space point of a single channel contributes an independent linear equation. If all channels of a phase-array receive coil are lumped together, a better estimation can be achieved because there are more equations. According to convolution theorem, the convolution kernel is the Fourier transform of the pixel-wise division between two images, *i.e.*: the B_1 map is proportional to $\arccos(F^{-1}(c(k)^*)/2)$.

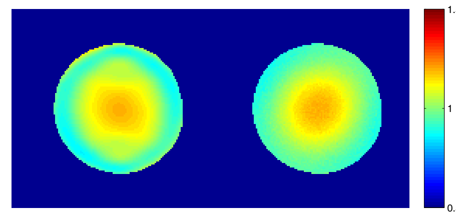

Figure 1. The B_1^+ map using convolution method (left) and double flip angle method (right) in a water bottle phantom. The color bar indicates the flip angle.

EXPERIMENTS: MRI scans of normal volunteers and a uniform phantom were acquired on a 3.0 T Siemens Trio-Tim system with a Siemens 12 channel head coil. The phantom images were acquired by spin echo sequence with the imaging parameters: FOV 180 mm, matrix 128x128, excitation flip angle of 120^o and 60^o, TR 2000 ms. The imaging parameters for human brain images were identical to those for the phantom images, excluding FOV 256 mm and TR 3000 ms.

RESULTS AND DISCUSSIONS: B_1^+ maps estimated in a water bottle phantom and in a healthy volunteer are demonstrated in Figs. 1 and 2. Both the convolution method and the pixel-divide method have similar results. But the convolution method has a smoother transmission field, without random noise or the influence of anatomical structure.

There are many factors influencing the accuracy or practical usefulness of B_1^+ maps techniques, including coil configuration, a subject, RF pulse configuration (shape, duration), accurate B_1^+ mapping should be estimated in real time for subject and RF pulse configuration [2], *e.g.*, most of conventional B_1^+ mapping methods, such as double flip angle method [3] requires image space pixel-wise division. When SNR is low, the common coil combine algorithm introduces signal bias as well as complex noise behavior. Therefore, the pixel-wise division based B_1^+ map is problematic. The proposed method utilizes k-space convolution to substitute image space pixel-wise division. Therefore, it does not have instabilities caused by small denominators. In addition, it avoids coil combine completely because it uses k-space data directly. Therefore, the proposed method easily combines with various sequences, k-space trajectories, and parallel imaging techniques to improve temporal-spatial resolution, accuracy and precision of B_1^+ maps.

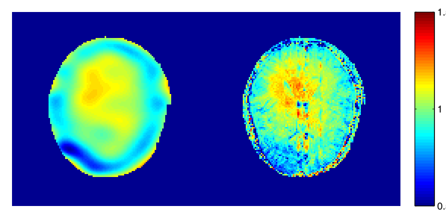

Figure 2. The B_1^+ map using convolution method (left) and double flip angle method (right). The color bar indicates the flip angle. It is obvious that the convolution method has a smother transmission field, regardless of the low SNR and the anatomical structure effects.

Since the convolution kernel has finite support in k-space, there is an intrinsic low-pass filtering effect in the proposed method. Comparing to the conventional methods, the proposed method finds the optimal solution at a given filter bandwidth in the least-square sense. Therefore, the proposed method is more robust when the SNR is low. It also avoids the bias introduced by coil combine which is a nonlinear process when the SNR is low.

CONCLUSIONS: Compared with conventional B_1^+ mapping methods, the proposed method can provides accurate, fast and robust B_1^+ maps for research and clinical applications.

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3. Stollberger R, Wach P. Magn Reson Med 1996; 35: 246.