B1 Field Mapping in-vivo for Three TEM Coil Modes at 8 Tesla

C. A. Mitchell[1], T. S. Ibrahim[2], D. W. Chakeres[3], R. D. Gilbert[3], P. M. Schmalbrock[3]

[1]Radiology, Uniformed Services University, Bethesda, MD, United States, [2]Electrical and Computer Engineering, University of Oklahoma, Norman, OK, United States, [3]Radiology, Ohio State University, Columbus, OH, United States

Introduction

Human ultra high field MRI frequently uses a TEM coil with n struts, which resonates in $(n/2+1)$ discrete modes [1]. These modes including the homogeneous mode have been shown in phantom studies to affect the patterns of receive sensitivity and flip angle [2] resulting in severe RF heterogeneity and therefore rendering the utilization of a single mode with standard RF excitation schemes ineffective. The objective of this work is to evaluate the use of three different modes for human brain imaging and to quantify the B_1^+ (excite) and B_1^{rec} (receive) fields

Methods

Using a single port/16 strut TEM coil, modes 0, 1 and 2 were individually tuned to 340.56 MHz for 8 Tesla imaging of a healthy human subject. Long-TR, spoiled gradient echo images were acquired for modes 0 and 1 with the excitation port (the connection to the transmit amplifier) placed anteriorly and posteriorly for both modes. Similar images were acquired in mode 2 for only posterior placement of the excitation port. The signal intensity in a spoiled gradient echo (GRE) sequence of flip angle θ, is given by

$$S(\theta) \propto B_1^{rec} PD \frac{\sin\theta(1-e^{-TR/T1})}{1-(\cos\theta)e^{-TR/T1}} e^{-TE/T2*} \approx B_1^{rec}(PDe^{-TE/T2*})\sin\theta \qquad \text{for } TR>>T_1.$$

where $\theta = \gamma \int B_1^+ dt$ and PD is the local proton density [3]. Using this equation, a function of the form $S_i = a_0 \sin(a_1 \cdot \theta_{nom,i})$ can be fit to the signal intensity in each voxel in a series of long-TR, GRE images covering a range of nominal flip angles ($\theta_{nom,i}$). The fitting parameters give the *relative* receive sensitivity (a_0) and *relative* flip angle (a_1) in each voxel. Twenty interleaved, sagittal slices were acquired with FOV/matrix/TR/TE of 20x20cm/256x64/4sec/6.2msec. Nominal flip angles were 30, 60 and 90˚. High resolution coronal images were subsequently obtained in the corresponding modes in 12 slices with FOV/matrix/TR/TE of 20x20cm/512x384/500msec/12msec and a nominal flip angle of 30˚.

Results

Figure 1 shows 3-D renderings of relative receive sensitivity (a_0) and relative flip angle (a_1) for modes 0,1 and 2 with the placement of the TEM excitation port as indicated. In this work, we refer to modes 0-2 as the first three modes in coil spectrum. Mode 0 is characterized by high B_1^+ and B_1^{rec} in the region proximal to the excitation port. Mode 1 demonstrates regions of both strong and weak B_1^+ and B_1^{rec} centrally. This trend explains central regions of weak signal noted in mode 1 images. Finally, mode 2 demonstrates strong B_1^+ and B_1^{rec} in lateral regions. Using these results, the high- resolution coronal images in figure 2 demonstrate that the medial signal strength in mode 2 compliments the low signal areas of mode 0 and 1.

Conclusions

Unlike that at low field strength, anatomic regions of interest in the brain can be targeted by the choice of TEM coil operating mode and placement of the excitation port. While mode 1 is often used for general anatomic coverage, areas of signal loss in this mode can clearly be seen in figure 1. Mode 0 can target structures near the excitation port, and mode 2 can target distal structures.
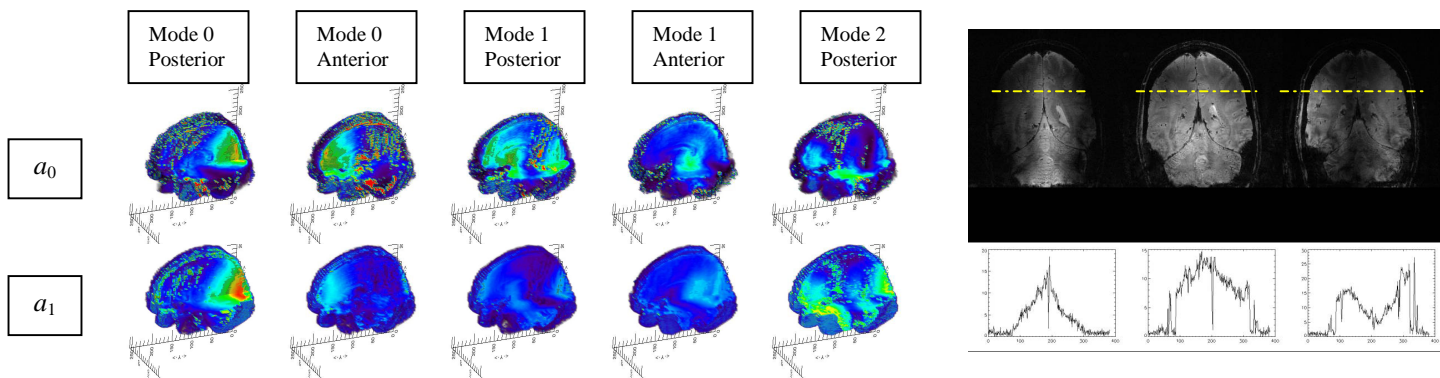

Figure 1: Three dimensional renderings of a_0 (B_1^{rec}) and a_1 (B_1^+) parameter maps with the mode and placement of the excitation port as indicated in the top legend. The left superior quadrant is removed for display.

Figure 2: GRE images for modes 0,1,2 (lt,cen,rt). The profiles show intensity across the yellow lines.

[1] Vaughan, *et. al.*, Magn Reson Med. 1994 Aug;32(2):206   [2] Ibrahim, *et. al., ISMRM Kyoto, Japan, P 488.*
[3] Haacke, *et. al.*, J. Wiley & Sons, New York, 1999