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Sensitivity of 3-D CSI-EPT Reconstructions to Modelled EM Field Variations and Object Truncation

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Introduction

Model-based electrical properties tomography (EPT; [1,2]) reconstruction with 3-D Contrast Source Inversion-EPT (CSI-EPT; [3,4]) has high potential, but is inherently sensitive to small errors in the model used. Here we assess its sensitivity to errors in the incident electromagnetic (EM) fields due to coupling of the coil to the sample (loading effect), errors in the total EM fields due to errors in B_1^+ mapping methods, and the effect of different object truncations.

Methods

We generated incident EM fields at 300 MHz (7T) from conduction currents simulated on a tuned head-sized birdcage coil model [5], loaded with either the "Duke" or "Ella" subject models [6]. Incident fields were also generated without the subject model, corresponding to an unloaded coil. The models had voxels of 3x3x5 mm and occupy object domains that range from 83x67x31 up to 83x76x55 voxels (Fig. 1).

First, we evaluated the influence of coil loading by using the incident fields from the different coil loading conditions together with the total field obtained in the "Duke" model. Then, we examined the effect of a B_1^+ mapping under/over-estimation by scaling the B_1^+ magnitude by a factor 0.8 to 1.2, and finally we analyzed the effect of truncation in the reconstructed object domain, in the case that the input data were generated using the full (untruncated) model.

Results

Fig. 2 shows that reconstructions are only slightly influenced by using the incorrect incident field, e.g. that produced by the coil when loaded with the "incorrect" model. Even in the case of using the incident fields from an empty coil, CSI-EPT still reconstructs all major tissue structures, albeit with significant smoothing.

Fig. 3 shows that a substantial global error in the B_1^+ magnitude does not result in a major loss of detail in the reconstructions.

Figs. 4 and 5 show the influence of different domain truncations. Fig. 4 shows the $|B_1^+|$ fields when the subject model was truncated at different levels within the neck. Realistic B_1^+ data is generated from models that are not truncated. Any difference in B_1^+ data between truncated and untruncated models propagates into the reconstruction. The reconstruction shown in Fig. 5b is performed on the full domain, thus ensuring that the object is completely captured, while Figs. 5c-f show the effect of truncation on the reconstruction domain. The most significant degradation can be observed in the region close to where the object is truncated (e.g. Fig. 5, coronal slices). The transverse cross-sections, all in the center of the coil, show a consistent reconstruction quality up to the truncation level of 12 cm, which reduces the domain size to around the level of the endring of the birdcage transmit coil.

Discussion & Conclusion

In CSI-EPT the contrast function is reconstructed, from which the electrical property maps can be derived. Figures 2,3 and 5 depict the absolute contrast function, showing how the reconstructions are influenced by the EM field variations and object truncation. The contrast function is a weighted combination of the conductivity and permittivity and its modulus does not directly reflect the individual electrical property maps.

Errors due to different loading of the coil or due to incorrect scaling of the $|B_1^+|$ have a minor influence on the reconstruction of the contrast function with CSI-EPT. Accurate electrical property maps can still be reconstructed.

In contrast, using a complete domain size has been shown to be important for CSI-EPT. The reconstructed domain should preferably contain the whole object inducing the measured B_1^+. If a smaller reconstruction domain is chosen, e.g. for reduced computational time, substantial errors can be introduced close to the region where the truncation occurs and the assumption of vanishing object is violated.

References
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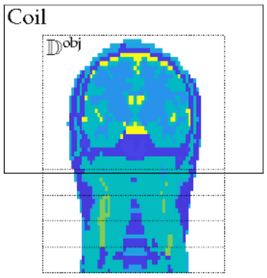
Figures



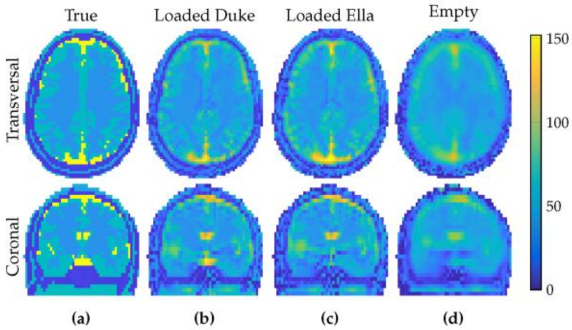


Fig. 2: Effects of loading on the reconstructions. The true absolute contrast function (a), and the reconstructed contrast function of the Duke head model after 10,000 iterations when the correct incident field is used (b), when the incident field from the coil loaded with Ella is used (c) and when the incident field from an empty ...sed (d).

Fig. 1: Two dimensional depiction of the position of the object inside the coil. This coronal view of the setup shows the outline of the coil and different sizes of the object domain D^{obj}.

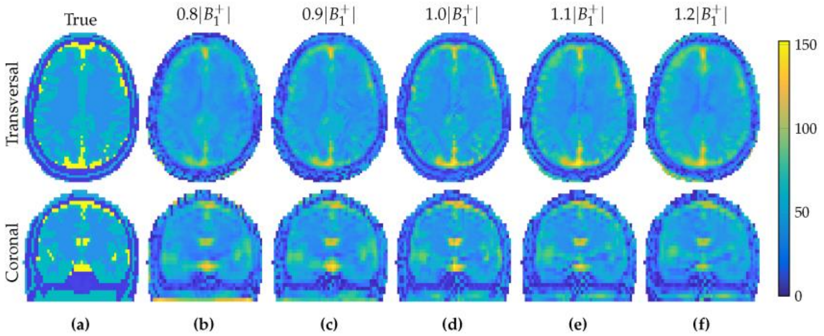


Fig. 3: Influence of errors in the B_1^+ magnitude on the reconstruction with CSI-EPT. The true absolute contrast function (a), and the reconstructions of 3-D CSI-EPT after 10,000 iterations when the scaling of the $|B_1^+|$ is underestimated (b,c), correct (d), or overestimated (e,f).

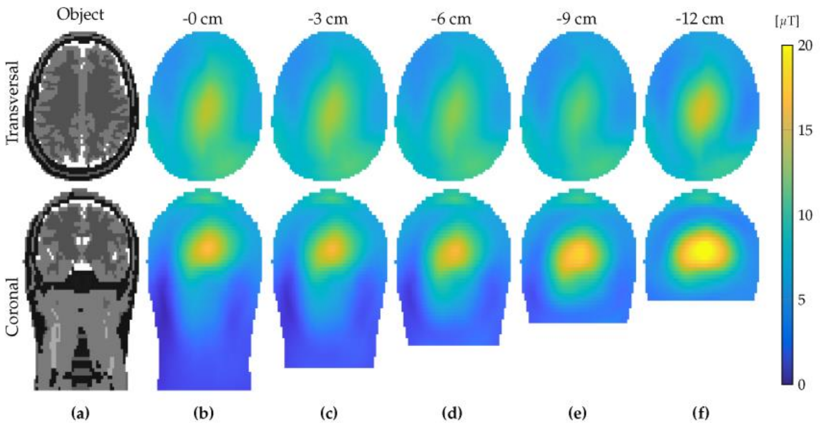


Fig. 4:The object (a) and the corresponding absolute B_1^+ distributions (b), and the B_1^+ distributions for shorter objects (c-f). The transversal slice is the slice in the center of the coil.

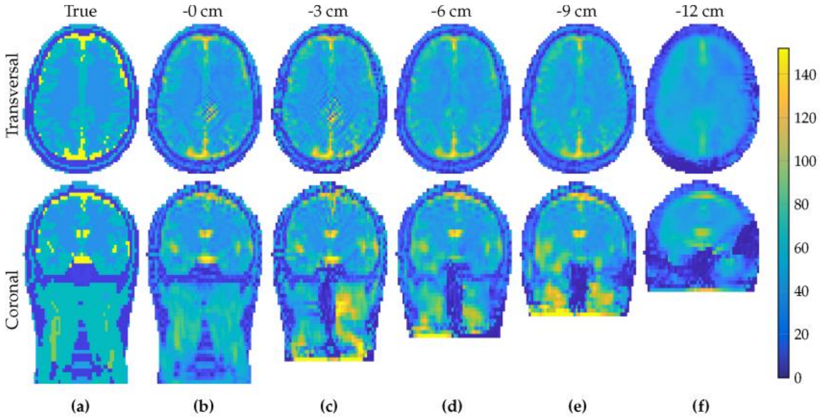


Fig. 5: Influence of the object domain size on the reconstruction of the contrast function. The true absolute contrast function (a), the reconstructed absolute contrast function when the domain is equal to the true object (b), and the reconstructed absolute contrast functions when the object domain is reduced by three, six, nine and twelve centimeters (c-f, respectively).