Correction of Dielectric Resonance Effect at 3T and above using B1-mapping

C. C. Guclu[1], A. Kocharian[1], H. Chung[1]

[1]Diagnostic Imaging, GE Healthcare-Technologies, Waukesha, WISCONSIN, United States

Introduction and Purpose

Dielectric resonance induced transmit field inhomogeneity has always been a nuisance in high field MR imaging, especially at 3T and above[1]. The root cause of dielectric resonance is the fact that at high field the wavelength in the body becomes comparable to human body dimensions. The resulting inhomogeneous B1 field (flip angle distribution) leads to (i) intensity non-uniformity, and (ii) contrast non-uniformity depending on the pulse sequence. In this paper, we investigated a method to remove the first symptom to improve the uniformity of the images.

Theory and Methods

The electrical permittivity (ε_r) modifies the wavelength (λ) in the tissue as $\lambda = \lambda_0 / \sqrt{\varepsilon_r}$, where λ_0 is the wavelength in free space. At 1.5T the λ in the body is approximately 52 cm, assuming an ε_r of 81 (this may vary depending on the tissue type). For a body scan of FOV=45cm, this means a relatively slow change of B_1 across the ROI. However, at 3T the λ gets halved, but at the same time ε_r drops approximately down to 60 since it is a function of frequency [2]. We finally get a λ of 30 cm (in-the-body), which is now comparable to the size of FOV, and large enough to cause image intensity distortion. Image uniformity correction techniques [3] used at 1.5T (and lower) fails to correct for dielectric effect, because these techniques mostly take the body coil image, which is already corrupted by dielectric resonance, as a reference. The overall flowchart of the proposed correction method can be summarized as shown in Fig 1. During the calibration scan three sets of images are acquired with breath hold. Total acquisition time is 18sec for all 3 sets. First two image sets are acquired with 35° and 70° flip angles using the surface coil (intended to be used) for the clinical scan. The last set is acquired with the body coil transmit/receive with 70° flip angle. The 1st and 2nd sets are used to calculate the flip-angle distribution using the double-angle method [4], whereas the 2nd and 3rd set of images are used to calculate the receive field distortion. Given the flip angle prescribed and the sequence type, we can approximately calculate the intensity distortion due to any flip angle inhomogeneity (3rd level in Fig 1). Combining these two pieces of information, we can correct for both receive sensitivity- and transmit field-induced intensity distortions in the clinical images.

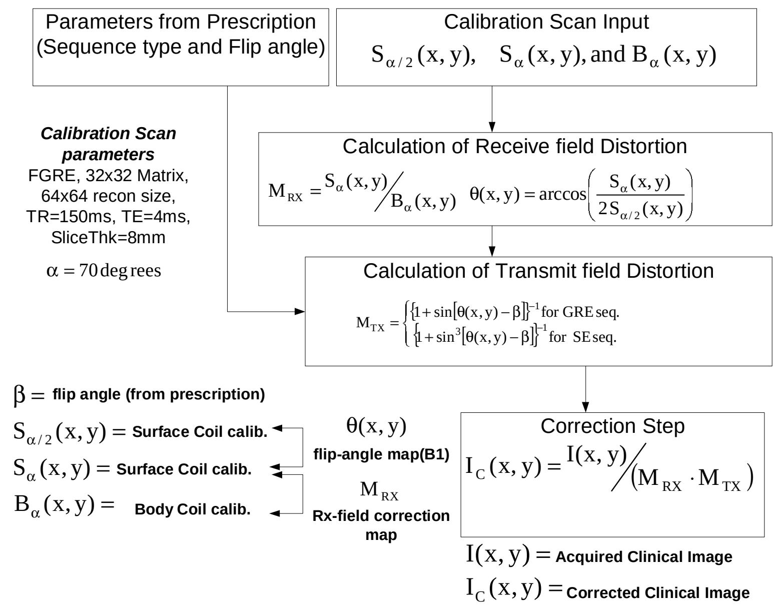

Fig 1: The flowchart of the image intensity correction process for high field systems (3T and above).

Results

Fig 2a-c show 3 sample body images: (a) original, (b) receive-field corrected only, and (c) receive and transmit-field corrected. These images were acquired using GRE sequence and a 8-channel body phased-array. The efficiency of the method was also verified using a body size phantom doped with NiCl.

Fig 2: A Sample liver+spleen image: (a) original, (b) rx-field corrected only, and (c) rx-tx-field corrected. The high intensity at the bottom of the spleen and the bright pixels are due to the cal-scan mismatch and the flow, respectively (not a result of the correction method)

Conclusion

We proposed a method to correct for both receive and transmit field distortions (dielectric resonance-induced) in a clinical scan at high field. Although in this study we used a 3T system, and applied the method to only GRE and SE sequences, higher field strengths and other hybrid pulse sequence types will benefit from this correction technique as long as an approximate flip angle-intensity relationship can be derived. Further verification using other pulse sequences is currently in progress.

References:

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