Design of a Local Shim Coil to Improve B0 Homogeneity in the Cervical Spine Region

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Introduction

B0 variation induced by the spatially inhomogeneous susceptibility distribution of the patient are a major challenge for application that rely heavily on B0 homogeneity such as EPI or spectral fat suppression techniques. In the abdomen, the major sources of B0-inhomogeneity are the lungs and the strongly asymmetric anatomy of the heart [1], while in the head, the sinuses and mouth generate major inhomogeneities. Another vulnerable region for B0 problems that has hardly been addressed is the transition from the upper thorax to the neck and head region. The shoulders are a strong discontinuity for the z-oriented B0 field and generate spatially large inhomogeneity. If the patient's anatomy does not allow the ability to place the neck region completely flat on the table, B0 fields penetrating in and out of the patient in the posterior neck region generate additional B0 inhomogeneity. This can become an issue, e.g. for spectral fat suppression techniques applied to cervical spine imaging.
Susceptibility pads [2] or other passive shims [3, 4] have been proposed for various applications and are partly commercially available. Nevertheless, most of the commercial products are bulky, costly and generate additional space limitations inside a local coil. Recently, the use of local shim coils and shim coil arrays for both static shimming and dynamic shimming especially at ultra high fields (UHF) has been proposed [4]. This work presents a very simple and robust approach to overcome static B0-inhomogeneities in the cervical spine region by using a local shim coil located inside the housing of a head neck coil.

Method and Experimental Setup

In order to design a local shim coil, the B0 inhomogeneities in the posterior neck region have to be characterized. This was done in a volunteer study with 8 healthy subjects on a Siemens MAGNETOM Skyra 3T system. B0-field maps were acquired in a central sagittal slice based on dTE phase differences to calculate B0 field deviations in ppm. The volunteer was placed on top of the Spine32 and HeadNeck20 coil in order to guarantee identical positioning with and without the shim coil. From this study, it was found that most volunteers exhibited a B0 field deviation of +2 to +4ppm in the region between neck surface and C6, while deviations of up to -2ppm were found close to C2/C3. It is straightforward that field variations of this order (>3.5ppm) make it impossible for spectral fat suppression techniques to achieve good results over the whole field of view.
With the field plots from the 8 volunteers and the mechanical limitations given by the housing of the HeadNeck20 coil, a local shim coil design was derived which can compensate most of the inhomogeneities for all the acquired datasets. The local shim coil setup consists of a single coil with 7 windings. The local shim coil has serial chokes to prevent RF interaction with the nearby local coils or the transmit fields and is driven by the PIN-diode current sources which are usually used for detuning the RF coils. Feeding the local shim coil with a current source originally meant for the local coils allows to change the shim currents in the graphical user interface and suppresses interaction with the gradient fields. With up to 6 pin diode channels in parallel, the local shim current can be varied from 0-0.6A in 100mA steps.
Fig. 1 shows a typical B0 distribution in a sagittal slice. Fig. 2 and Fig. 3 show results for spectral fat suppression for a critical volunteer with and without the local shim coil.

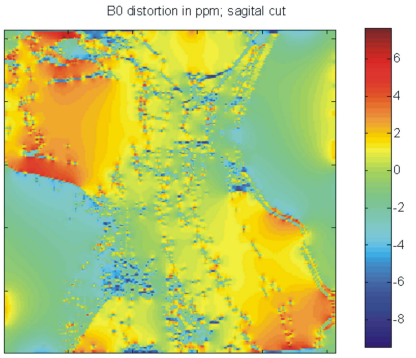

Fig. 1: typical Bo distribution (in ppm)

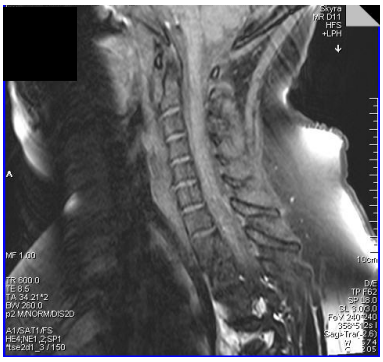

Fig. 2: critical patient without local shim

Fig. 3: critical patient with local shim

Results and Discussion

Based on both qualitative image assessment and a quantitative analysis of the B0 homogeneity distribution, it could be shown that a significant improvement in spectral fat suppression for the cervical spine and neck region could be achieved using only a single channel local shim coil inside a local coil. An improvement could be seen for all of the 8 volunteers, with subtle improvement for uncritical and significant improvement for critical cases. The SNR of the local RF coil due to the close proximity of the local shim coil was not degraded. In order to achieve best results for a large patient population, a static but patient adaptive local shim seems to be sufficient. One major challenge for shimming field inhomogeneities generated by the susceptibility of the patient is the large variability of the human anatomy. Inhomogeneities with higher spatial complexity or larger variations in the anatomy may be taken into account by the use of local shim coil arrays, although a perfect compensation of all inner field sources by using external coils is not possible according to the fundamental laws of magnetostatics.

References

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