High quality whole brain MP2RAGE at 7T: utilization of thin dielectric pads

Kieran O'Brien[1], Tobias Kober[2], Jose Marques[3], Francois Lazeyras[1], Rolf Gruetter[1,3], and Gunnar Krueger[2]

[1]*CIBM, University of Geneva, Geneva, Switzerland,* [2]*Advanced Clinical Imaging Technology, Siemens Healthcare IM S AW, Lausanne, Switzerland,* [3]*CIBM-AIT, Ecole Polytechnique Fédérale de Lausanne & Univertisy of Lausanne, Lausanne, Switzerland*

Introduction: High quality whole-brain structural scans at ultra high field are challenging due to the large B0, radiofrequency (RF) transmit and receive field inhomogeneities. A new sequence, MP2RAGE [1,2], has recently been introduced that provides images of uniform contrast throughout the brain. However the quality of this "uniform" image is highly dependent on the effectiveness of the adiabatic inversion pulse. At ultra high fields, the large B0 inhomogeneities require the frequency sweep of the adiabatic inversion pulse to be increased at the expense of an increase in the RF power required to fulfill the adiabatic condition [2]. Consequently, regions of the brain which experience a low RF power, such as the cerebellum and temporal lobes, have poor inversion. The use of alternative adiabatic pulses such as an HS8 [2] or an optimized TR-FOCI [3], which can achieve inversion at a lower RF power, has been shown to improve the inversion coverage [4], but in subjects whose head size is large relative to the physical "z" coverage of the transmit coil, complete coverage of the cerebellum remains problematic. High permittivity dielectric pads (ε≈80) have been used to improve the uniformity of the RF distribution in liver imaging at 3T and recently, very thin pads have been proposed at 7T in the brain [6] using Barium Titanate (ε≈165). The purpose of this study was to investigate the ability of the very thin dielectric pads to consistently improve the inversion efficiency in the cerebellum for whole-brain MP2RAGE acquisitions.

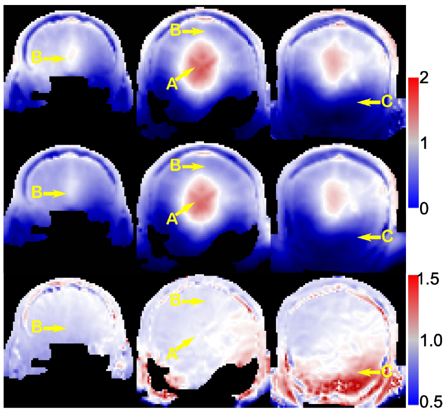
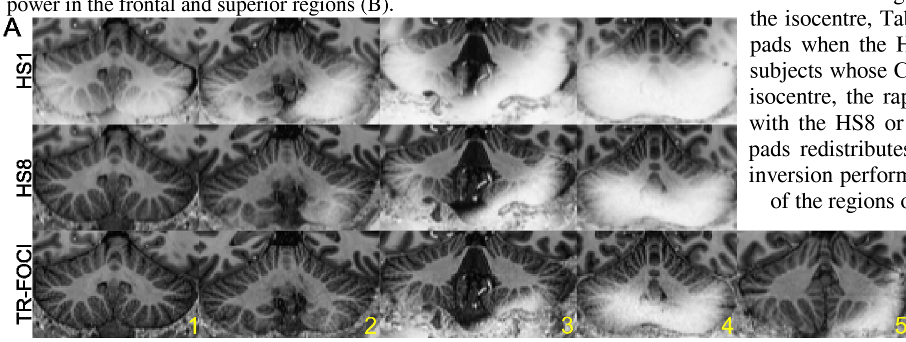


Figure 1. 3 Coronal cross sections (columns) of the relative B1 maps without (top row), with (centre row) dielectric pads and their ratio (bottom row) for subject 4 (1=system's ref. voltage). The dielectric pads attracts the RF field's hot spot (A) towards the Cerebellum (C), increasing the RF power at the expense of the RF power in the frontal and superior regions (B).

Methods & Materials: Whole-brain B1 maps and MP2RAGE image volumes were acquired in five subjects on a Magnetom 7T whole-body scanner (Siemens Healthcare Sector, Germany) with a single-channel transmit and 32 channel receive volume coil (Nova Medical Inc, MA, USA). Subjects were carefully positioned as deep into the coil as possible and were initially scanned without dielectric pads. Subjects that exhibited poor inversion efficiency in the Cerebellum underwent a repeat scan session with 3 dielectric pads: one placed under and two placed on either side of the neck. Each pad measured 110x110x5mm^3 with a Barium Titanate volume-to-fluid ratio of 25%. The complete scan protocol consisted of: i) B1 maps obtained with a SA2RAGE [7] (TR/TE 2400/0.72ms, Matrix 116x128x64, voxel 2.3x2.3x4mm); and ii) MP2RAGE acquisitions using the three different adiabatic inversion pulses: HS1/HS8/TR-FOCI [4] (TR/TE/TI$_1$/TI$_2$ 5500ms/2.84ms/750ms/2350ms Matrix 300x320x208, voxel 0.9x0.9x0.9mm). The B1 amplitude of the adiabatic pulse used for the MP2RAGE was chosen to be either the peak amplitude available on the system (HS1), or the B1 amplitude that complied with the manufacturer's specified SAR limits (HS8/TR-FOCI).

Results: The relative B1 maps, Figure 1, show the effect of using the dielectric pads. The pads cause the "hot spot" of the RF distribution to move from the isocentre towards the cerebellum. The available RF power redistributes over the cerebellum with increases of up to 50% (Change in the μ±σ relative B1 for subjects 3, 4, and 5 was 0.34±0.11→0.51±0.13 / 0.25±0.08→0.37±0.11 / 0.40±0.04→0.58±0.05 respectively). A modest improvement is experienced in the temporal lobes (0.42±0.12→0.42±0.10 / 0.47±0.11→0.55±0.13 / 0.39±0.12→0.42±0.17). But the improvement comes at the expense of reduced RF power in the anterior and superior regions of the head (0.78±0.06→0.77±0.06 / 0.81±0.05→0.74±0.08 / 0.90±0.09→0.82±0.09).

In cases when the inferior edge of the subject's Cerebellum is no further than 75mm from the isocentre, Table 1, complete inversion is possible without the dielectric pads when the HS8 or TR-FOCI adiabatic pulses are used, Figure 2. In subjects whose Cerebellum's inferior edge is further than 75mm away from isocentre, the rapid fall-off in RF power hinders complete inversion even with the HS8 or TR FOCI adiabatic pulses. Introduction of the dielectric pads redistributes the RF field towards the Cerebellum and improves the inversion performance of each adiabatic pulse, visible by the disappearance of the regions of high intensity.



Head dimensions (mm)

Subj	1	2	3	4	5
AP	191	185	188	186	188
SI	136	150	136	148	137
RL	138	151	141	158	137
IC	65	72	77	86	83

Table 1 Anterior-posterior (AP), superior-inferior (SI), right-left (RL) dimensions of each subject's head, and the distance from isocentre to the inferior edge of the cerebellum (IC) measured on the 3D MP2RAGE image.

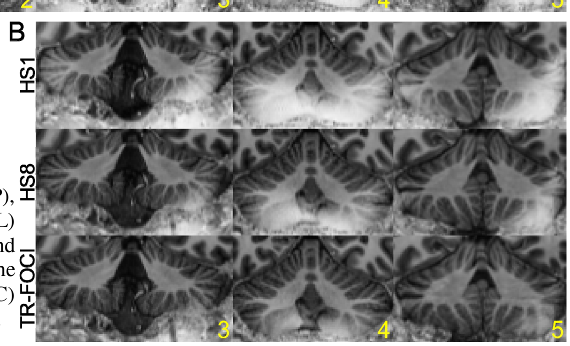


Figure 2 Coronal cross-section of the cerebellum for each subject (columns) shows the effect of using different adiabatic inversion pulses (rows) without (A) and with (B) the dielectric cushions. In the "uniform" image, poor inversion is characterised by bright signal intensity. The HS8 and TR-FOCI pulses have improved inversion efficiency relative to the HS1 pulse. Importantly for subjects whose cerebellum is far from isocentre, the dielectric pads increase the RF power available to cause inversion.

Discussion: In a subject where the cerebellum's inferior edge is located further than 75mm from isocentre then the RF power available in the cerebellum is not sufficient to ensure proper inversion, even when low RF power adiabatic pulses are utilized [4]. Introducing thin dielectric pads as proposed in [6] enables the RF distribution's hot spot to be shifted from isocentre towards the cerebellum, increasing the RF power and inversion efficiency of each adiabatic pulse. The small loss of RF power in the anterior and superior regions of the head is manageable as the native RF power is higher and therefore does not affect the inversion efficiency.

In conclusion, dielectric pads positively redistribute the RF field to favor full inversion in the cerebellum and in conjunction with low RF power adiabatic pulses ensure high quality whole-brain coverage in 3D MP2RAGE scans to be obtained across subjects.

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